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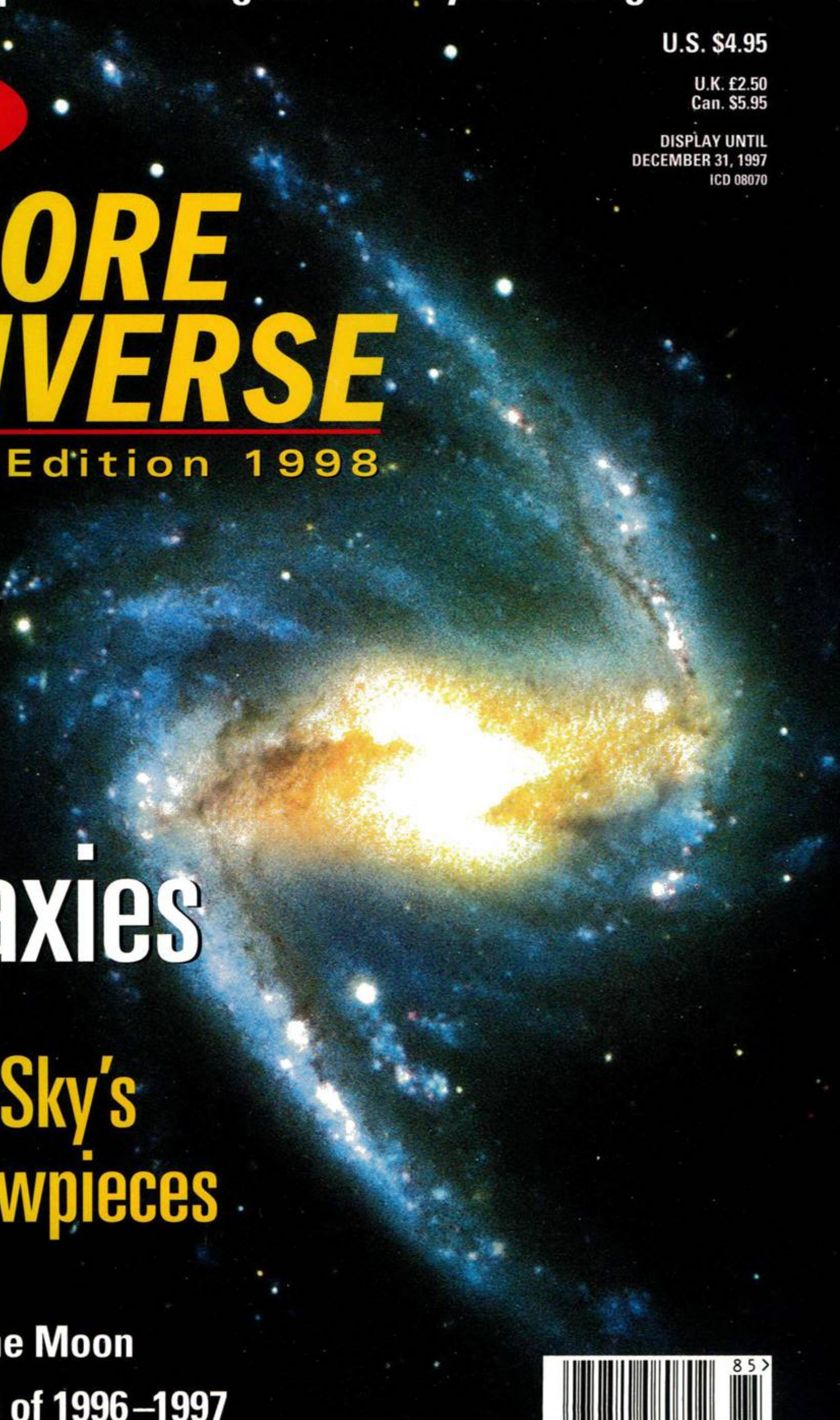

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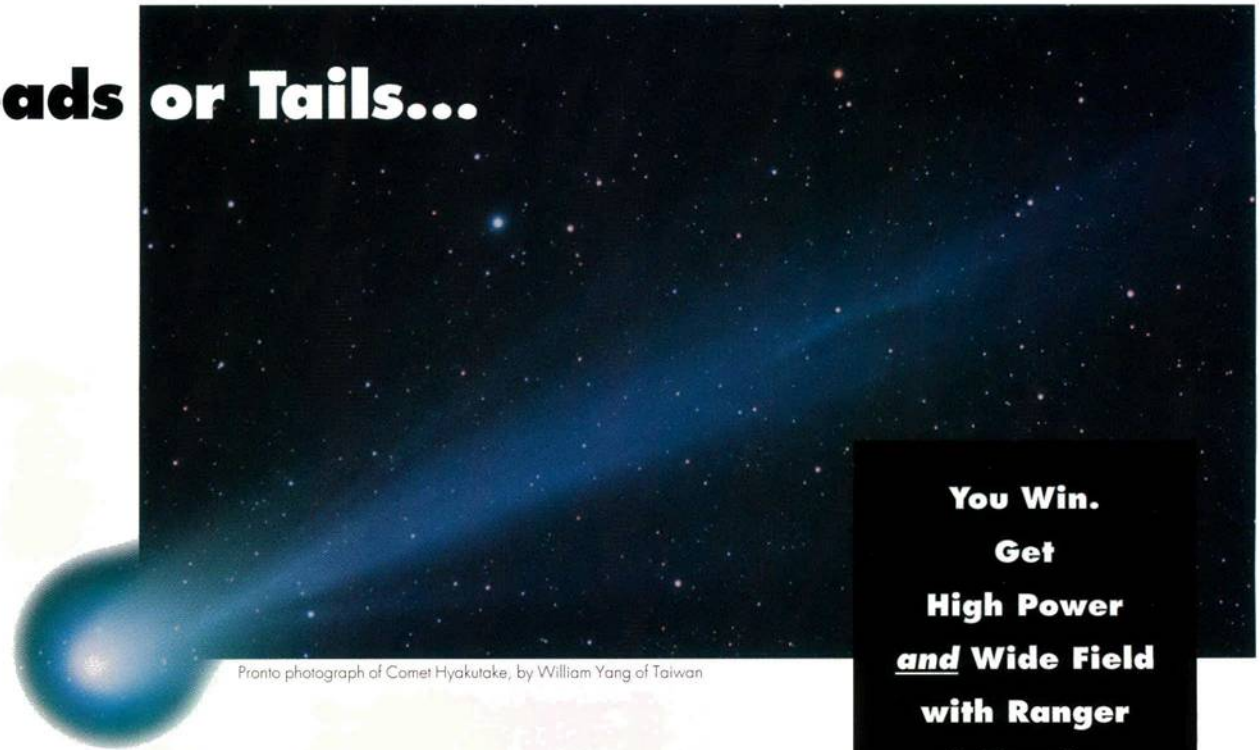
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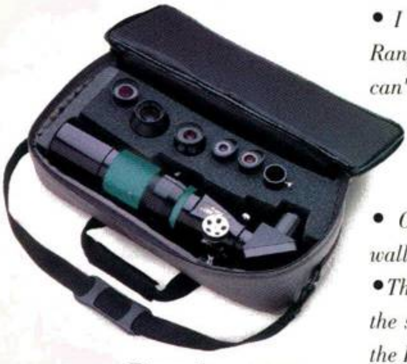
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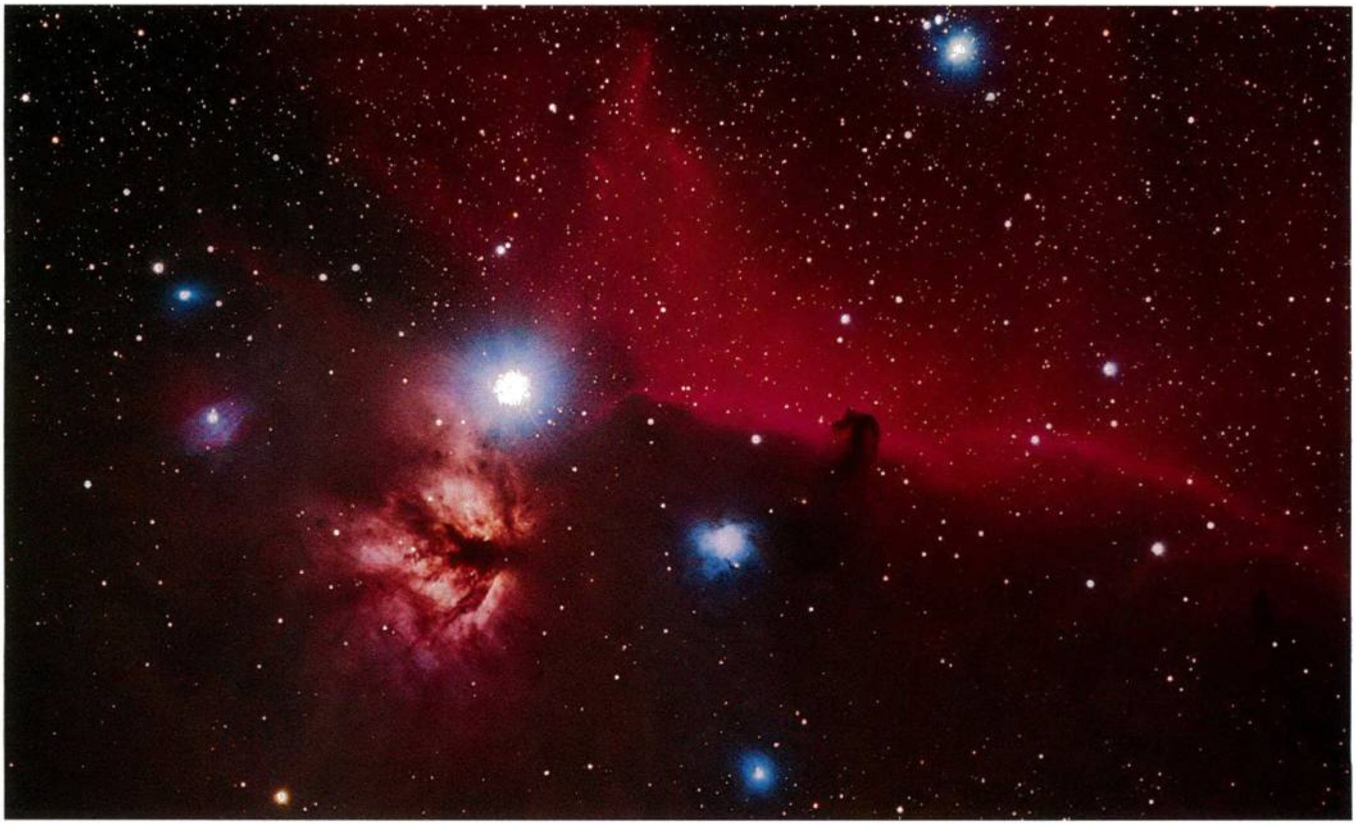

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Journey Across the Cosmos

From nearby planets to distant quasars, with stops at virtually every imaginable object in between, we take you on a wondrous trek through our glorious universe. *Neil Savage*

Cover photo
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Kevin Gill and Tom Polakis

To an extent undreamed of a scant few years ago, powerful software for personal computers and the Internet's amazing depth and breadth offer a smorgasbord of delights for backyard and armchair astronomers alike.

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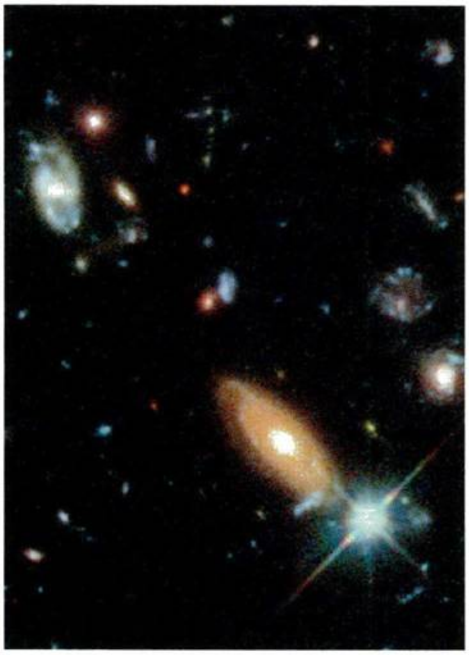
Our readers took some beautiful images this past year, capturing the majesty of Comet Hale-Bopp as well as the grandeur of many perennial favorites.

At *the* Eyepiece

A Fantastic Voyage

Backyard astronomers, casual skygazers, amateur cosmologists, and armchair space explorers have never had it so good. Just two decades ago the universe for those who love the sky was a vastly simpler place, one without the fruits of the Voyager missions in the solar system or the Hubble Space Telescope and its outstanding portraits of the distant universe. And telescopes and imaging equipment were vastly smaller and simpler. I can remember reading numerous guides that told us that the Veil Nebula in Cygnus was out of the reach of backyard instruments in the hands of hobby astronomers. But we didn't listen. We tried to find the spectacles of the galaxy and in most cases succeeded, pushing the limits of amateur astronomy in the process.



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Voyage to the Early Days of the Universe: Distant Galaxies

Now, approaching the new millennium, our understanding of the solar system, the galaxy, and the universe at large has matured. Spacecraft have visited the planets and done the basic data gathering, with the exception of Pluto, that forms a basis for understanding their character. Astronomers understand the violent nature of the heavy bombardment period of the early solar system, the K-T impact on Earth, and the real danger posed by Earth-crossing objects. They are transforming their comprehension of the relationship between asteroids and comets. And they are reaching out of the solar system and finding, to nearly no one's surprise, planets surrounding nearby stars.

Deeper into the universe, astronomers are converging on an accepted value for the Hubble constant and seem to be moving toward a slightly younger, smaller universe. Hypotheses like inflation have moved into the mainstream, allowing cosmologists to begin to get a handle on how the whole mess began in the first place.

And in the backyard, more objects are visible now than ever. Not only are the telescopes larger, enabling much fainter objects to be viewed and much more detail to be seen in the brighter objects, but a dazzling array of information is now out there along with sophisticated accessories like specifically targeted narrow bandpass nebular filters.

With all this in mind, I invite you to take a fantastic voyage. No, not like in the cheesy Raquel Welch movie about floating through some guy's bloodstream. Rather, travel through the scope of the whole universe with writer Neil Savage in his article "Journey across the Cosmos," on page 8. *Bon Voyage!*

Dave Eicher
Editor

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Journey Acro

by Neil Savage

WHEN I WAS 12 OR 13, I gazed at the stars from the bathroom window. We lived on a hill, and through that window I could see the neighborhood dropping away, houses dwindling among the treetops with increasing distance, and a panorama of the sky. I would stare into the vastness of space and wonder if anyone out there was looking back toward me, another kid, in another bathroom, in an alien house on a hill on a planet orbiting another star.

Not, I suppose, a startlingly original thought, but it is one shared by generations of stargazers, from the purely romantic to those who have devoted their lives to staring out into space. In fact, most of what scientists have learned about the universe comes simply from looking, from monitoring, and from measuring the information that arrives on the wings of starlight. Our only contact with the distant cosmos is the light, and other forms of radiation, it pours down on us. Knowledge of our solar system neighbors has come a little easier through the work of a small phalanx of probes and a little bit of manned exploration. Slowly, we've learned a lot about the way the universe works and our place in it.

Let's take a tour of the universe, and visit some of the strange and wondrous places astronomers have investigated.

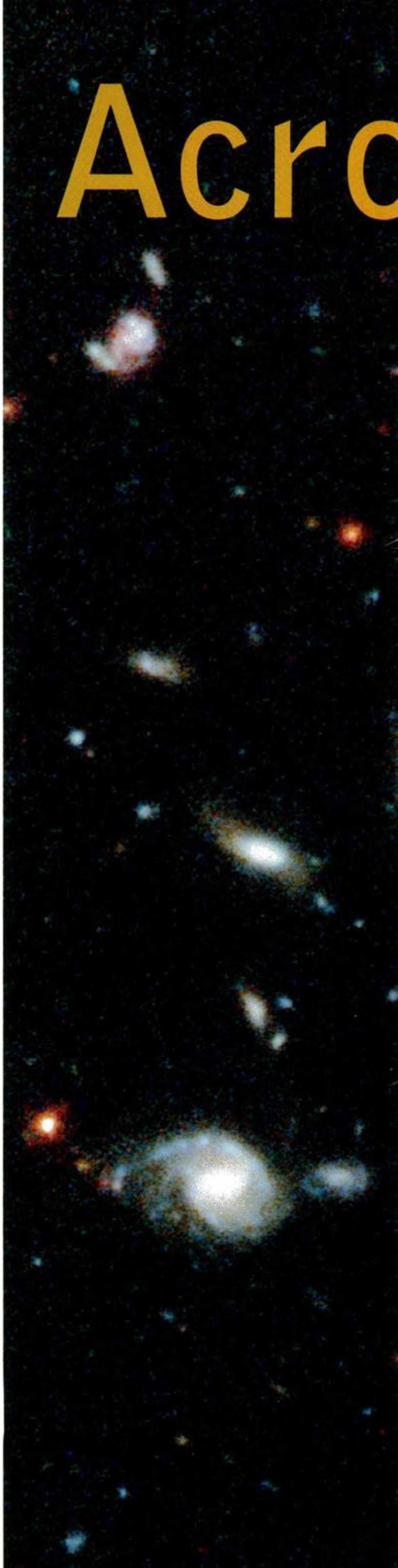
The Sun

We'll start with the most prominent object in the neighborhood: the sun. This, pretty much, is the solar system. Of the matter in the solar system, 99.8 percent is situated in this huge, hot ball of gas. Everything else — Jupiter, Halley's Comet, your house, Dennis Rodman — makes up the remaining one-tenth of one percent.

You could string 109 Earths across the sun's 865,000-mile diameter. At 60 miles per hour, it would take 1.6 years to drive across it, assuming your Chevy's engine didn't overheat first. The sun is 92 percent hydrogen, and its Jupiter-sized core is a gargantuan nuclear fusion reactor fueled by pressure and temperature, wherein hydrogen atoms combine to form helium. This reaction creates enough energy in one second to keep the United States running for 7 million years. Our star is middle aged, it has enough hydrogen to fuel its nuclear furnace for another 5 billion years.

It takes individual packets of light energy several million years to make the 400,000-mile journey from the core to the surface, zigzagging in tortuous paths as they fight their way through dense layers of gas. Our star appears slightly yellowish because its surface temperature is about 6,000 kelvins (10,000° F), though its core temperature reaches 15 million kelvins.

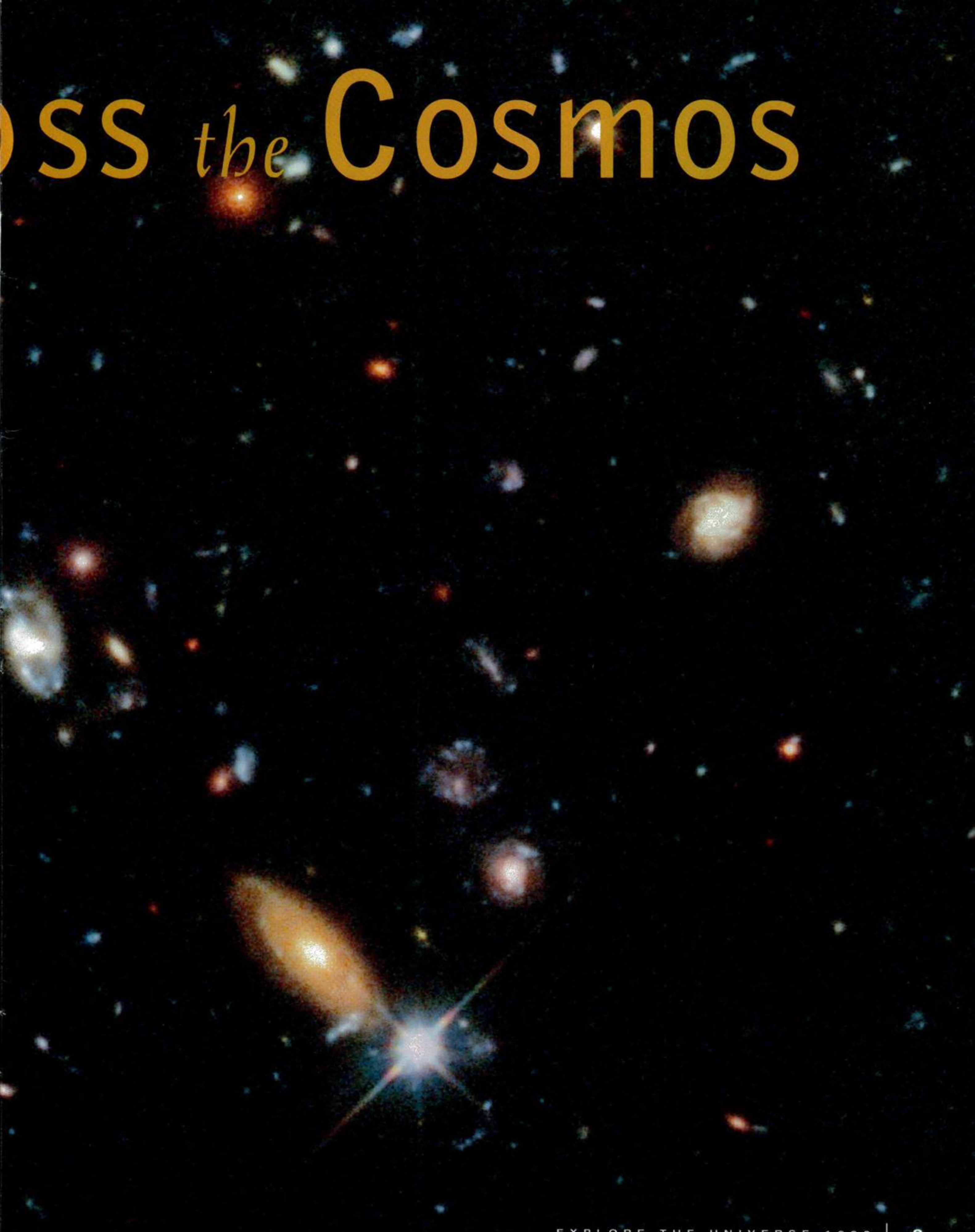
Like Earth, the sun rotates on its axis. Because it's made of gas instead of rock, the entire sphere doesn't have to spin at the same rate. The equator spins faster (once every 24 days) than the poles (once every 30 days). This "differential rotation," coupled with the sun's powerful magnetic field, makes the surface erupt in sunspots, flares, and prominences that follow a cycle averaging 11 years. The most violent flares

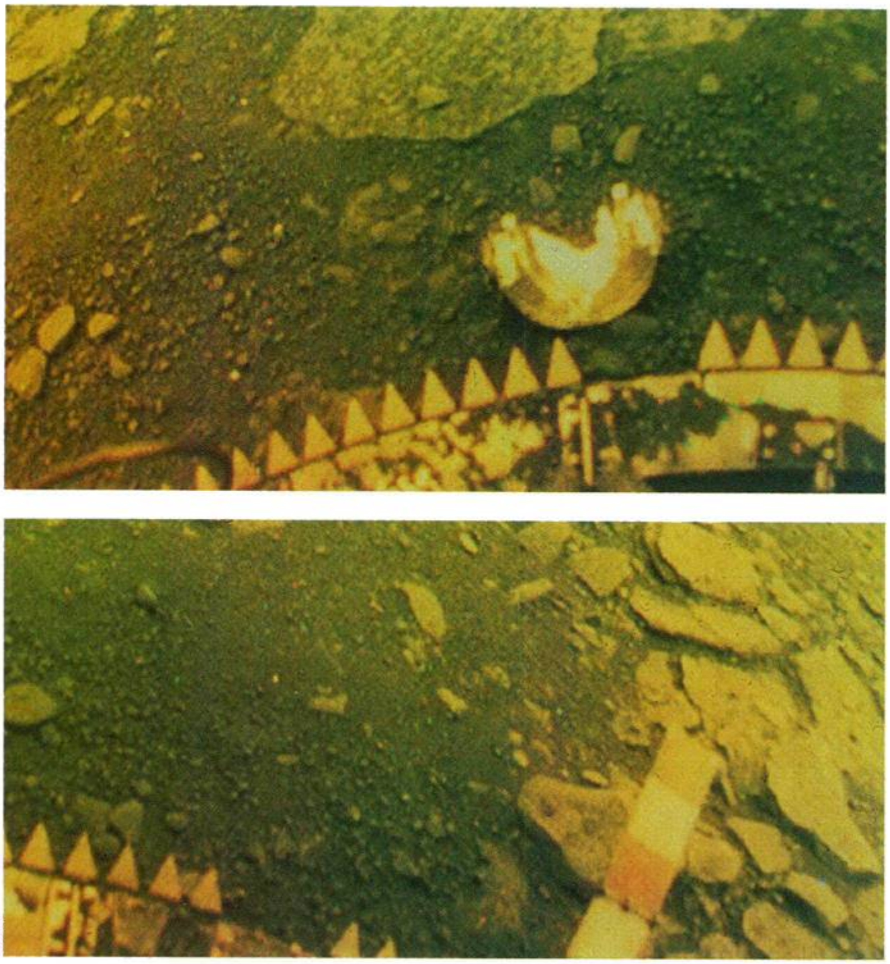


The Hubble Space Telescope stared at one spot in space for 10 straight days, catching the light of galaxies that date back to very near the beginning of space and time.

Robert Williams and the HST Deep Field Team (STScI) and NASA

oss *the* Cosmos





The only glimpses of Venus's hellish surface came from the twin Soviet Venera landers, which survived the 850° F temperatures and crushing air pressure for 50 minutes.

Sovfoto

release millions of times the energy of an atomic bomb and can wreak havoc with TV reception.

Parts of the sun's wispy outer atmosphere — the corona — have temperatures of 100 million kelvins, even hotter than the core. Scientists still don't know why the corona is so hot. Despite the searing temperature, coronal material is so tenuous that if you put some in a jar, you could stick your hand in it and would feel nothing at all.

The sun also gives off a stream of electrically-charged subatomic particles called the solar wind, which bathes all the other bodies in the solar system. Near solar maximum, solar wind particles captured by Earth's magnetic field will cause aurorae to dance and shine more brightly and could burn out communications satellites.

The sun and the rest of the solar system formed 4.6 billion years ago. An enormous cloud of gas and dust began to collapse under the force of gravity, forming several dense clumps inside. These clumps started shrinking under the force of gravity, spinning faster and faster just as a figure skater spins faster as she brings in her arms. Stars formed in the centers of these clumps, where the densities of gas were the highest. In the case of the sun, the spinning clump flattened into a swirling disk of gas and dust. The dense, rocky, inner planets formed near the sun, while the gas giants formed farther out. The cloud's original spin is still here, which is why all the planets revolve around the sun in the same direction as the sun rotates.

Mercury and Venus

Mercury, a crater-pocked planet with virtually no atmosphere, orbits closest to the sun at a distance of 36 million miles, a little over a third of Earth's distance from the sun. Daytime temperatures soar to 800° F (427° C). Because it is so close to the searing heat of the sun, Mercury is made of heavy materials that can exist as solids at high temperatures, such as nickel, iron, and silicates. As a result, Mercury is the second densest planet after Earth.

Mercury is only 3,000 miles across, the distance between New York and San Francisco, and has about 1/18 Earth's mass. This little planet has been geologically dead for three or four billion years, and has been marred by huge meteor impacts. It has a thick iron core that fills most of the planet's interior. Some scientists have speculated that it may actually have been hit so hard and so often that most of its rocky crust was torn away.

Being so close to the sun's powerful gravitational clutch, tidal effects have slowed the planet's rotation to a crawl: Mercury completes one rotation every 59 Earth days. That's exactly two-thirds of a year on Mercury, which runs only 88 Earth days. It takes 176 Earth days (two Mercury years) on average to go from one sunrise to the next.

Long days mean long nights. Without an appreciable atmosphere to spread the heat around, the unlit portions of Mercury can get as cold as –280° F (–173° C). Ice apparently exists in deep polar craters where the sun, which always hovers precisely over the equator, never shines. That would explain the reflections astronomers got bouncing radar off the planet.

Farther out, Venus was once considered Earth's twin. Our sister planet is slightly smaller, 7,520 miles in diameter compared with Earth's 7,926, and it is 82 percent as massive. Like Earth, Venus has a nickel-iron core, which is surrounded by a thick mantle of igneous rock and a rocky crust. To find out how much you would weigh on Venus, multiply your weight by 0.91. But you wouldn't want to actually stand on Venus's surface. It is a hellishly hot 860° F (460° C), and the atmospheric pressure at the surface is 90 times higher than the pressure at sea level on Earth. Breathing on Venus would be like trying to inhale burning crude oil. The atmospheric pressure would crush you into virtual nothingness as most of the molecules in your body instantly vaporized.

Why is Venus a veritable hell? Venus orbits 25 million miles closer to the sun than Earth, causing it to lose its water early in its history. Volcanos that formed in the early days of the solar system belched huge amounts of carbon dioxide into the atmosphere. On Earth, the oceans sucked up a large

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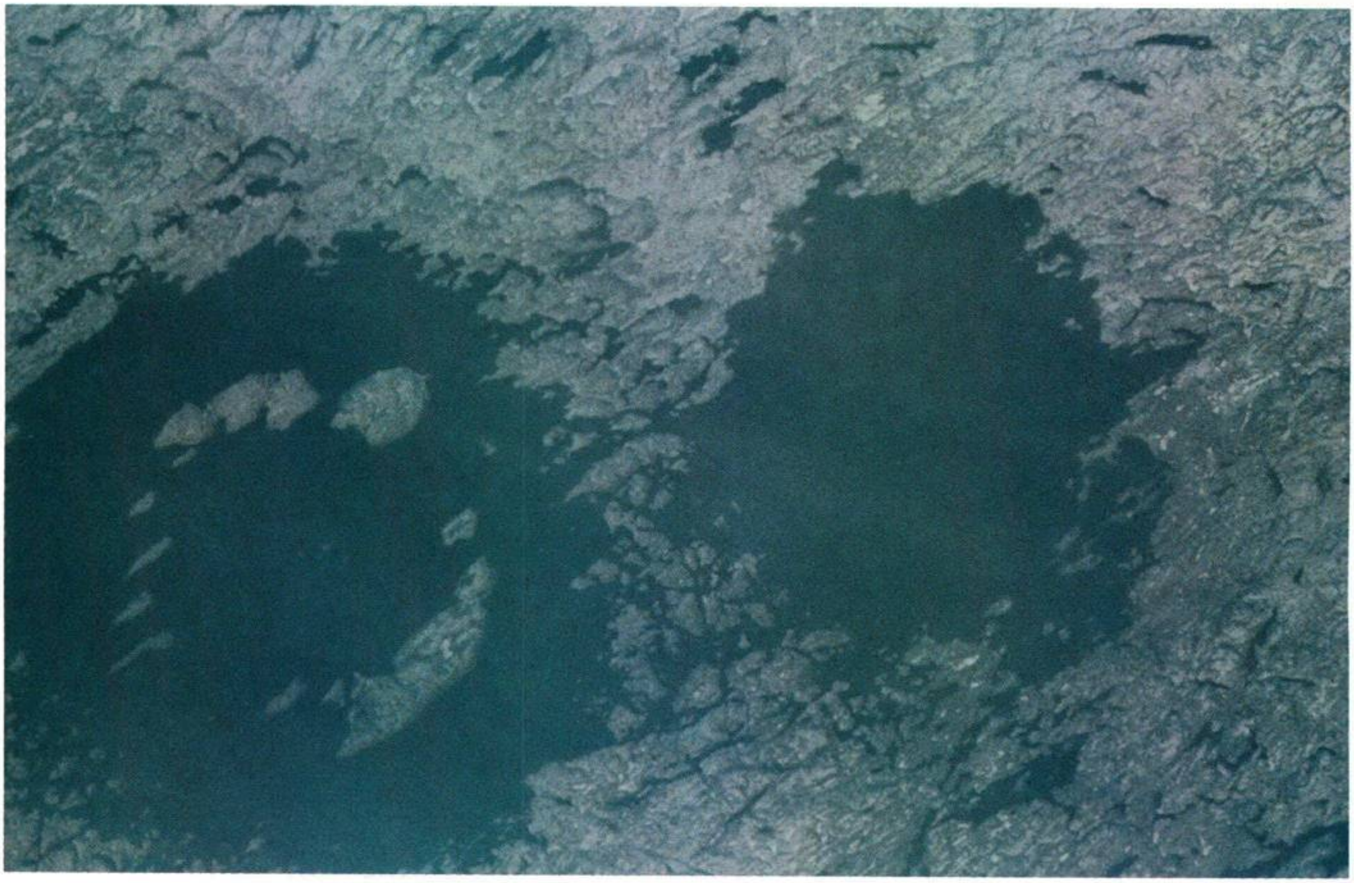
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The Clearwater Lakes in Manitoba, Canada, testify to the battering Earth has suffered throughout its history.

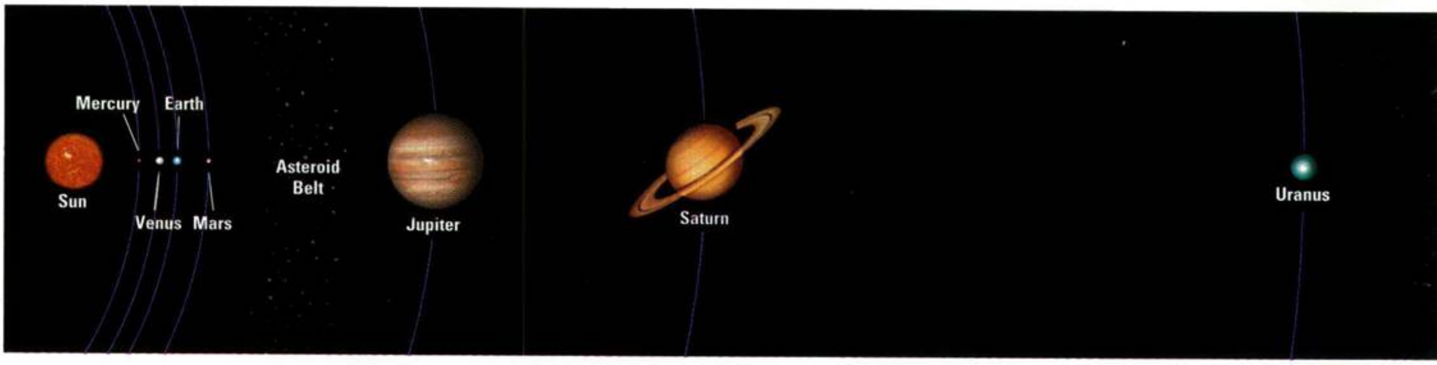
portion of the carbon dioxide. But Venus, without oceans, kept most of its carbon dioxide in the atmosphere. Though both planets probably started out with similar amounts of carbon dioxide, Earth's atmosphere today is less than 1 percent carbon dioxide whereas Venus's is about 96 percent. As anybody knows who has followed the global warming debate, carbon dioxide is a greenhouse gas — it traps heat in the atmosphere. So a planet that would have been pretty hot from being close to the sun got even hotter and stayed that way.

Yellow sulfuric acid clouds obscure Venus's surface from view. It took radar imaging to get a picture of the surface. Venus features giant volcanos that are higher than Mt. Everest, some of which may still be active. There are a couple of Australia-size continent-like structures, but Venus apparently lacks the drifting crustal plates of Earth. And while there are meteor impact craters, none appear to be much older than 600 million years. The lack of older craters suggests that volcanic activity resurfaced the entire planet 600 million years ago, covering up evidence of more ancient impacts.

Venus also has a weird calendar. Its year lasts 225 Earth days. But it takes a ponderous 243 Earth days to spin once on its axis. Moreover, Venus spins the "wrong" way — in the opposite direction of Earth's spin and the spin of most of the other planets. So on Venus, the sun rises in the west and sets in the east. When these effects are combined, a rather complicated affair too involved to explain here, daylight and nighttime each lasts 58 Earth days. Because of the thick atmospheric blanket, however, one would never see the sun — even at high noon the venusian sky is comparable to an overcast day on Earth.

Earth and Moon

Maybe it's a parochial view, but Earth provides a convenient measuring



Astronomy: Elisabeth Rowan

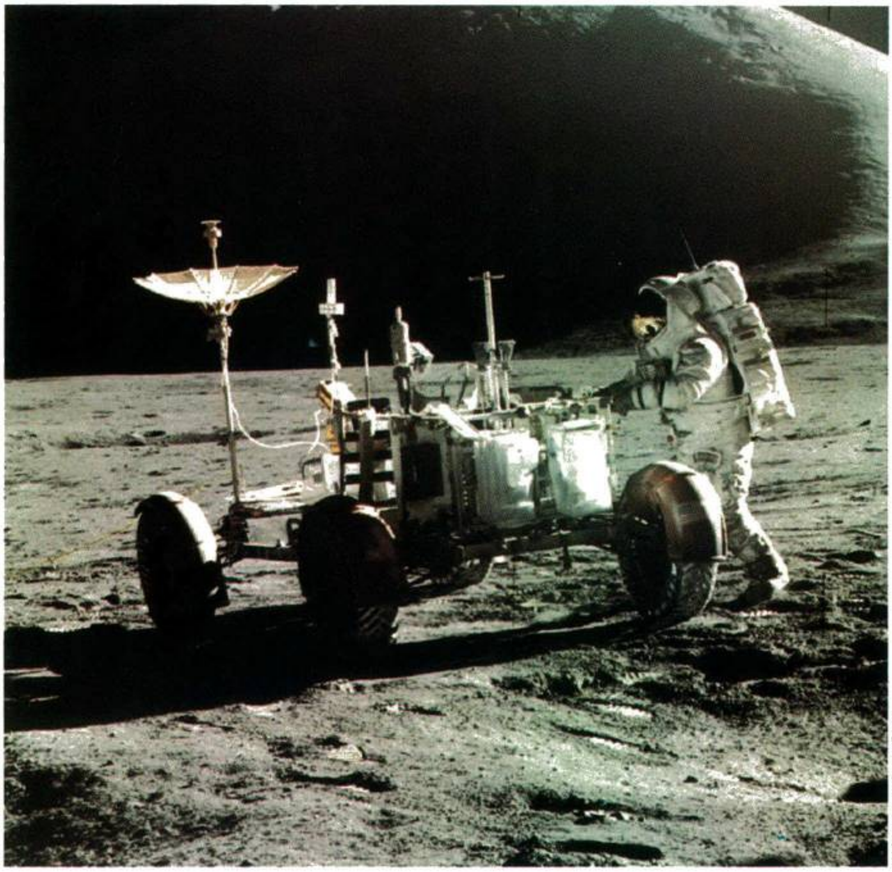
stick for solar system distances. Astronomers call the average Earth-sun distance, 93 million miles, an astronomical unit (AU). The Chevy that drove across the sun's diameter in a year and a half would take 177 years to travel one AU. Light, the fastest thing in the universe at 186,282 miles per second, takes a mere eight minutes.

Earth stands out as the largest of the rocky inner worlds. With a density 5.5 times that of water, Earth is the densest planet in the solar system. It has a nickel-iron core and a mantle and crust made of basalt and granite. The molten core spins faster than the rocky mantle above it. The spinning core gives Earth one of the strongest magnetic fields in the solar system, a field that sometimes flips polarity. The magnetic field channels charged solar wind particles to the poles, creating the aurorae.

Earth is geologically active, although the rate of activity is gradually slowing over the eons as the planet slowly radiates its internal heat into space. Like a cracked egg shell, the crust is broken into a dozen or so pieces called plates. The plates float on the hot, dense rocks of the mantle. Plates collide with one another to form mountain ranges or they split apart to form rifts. The motion of the plates drives continental drift, volcanism, and earthquakes.

To an alien being observing Earth through a telescope, the most startling aspect of the planet would be its atmosphere. Nitrogen makes up 78 percent of Earth's air and oxygen comprises 21 percent (the remaining 1 percent is mostly argon, with some carbon dioxide and other trace gases). The extraterrestrial would know from that blend that there's life here. Oxygen is highly reactive — rusting cars and burning forests give evidence of how easily it combines with other molecules. There's no way the atmosphere could retain that much oxygen unless it were being constantly replenished. Oxygen is in such abundance because plants exude it as a waste product of photosynthesis.

Another unusual aspect of Earth is its relatively large moon. Except for the Pluto-Charon system, most planets dwarf their moons, and the innermost two planets have no moons at all. But our moon is a quarter Earth's diameter, and its gravity is strong enough to produce substantial tides on the planet. The moon orbits Earth at an average distance of 239,000 miles, and takes 27.3 days to complete a circuit. That Chevy, doing 60 miles per hour, would take 166 days to get there; Apollo 11, traveling considerably faster, took only three days.



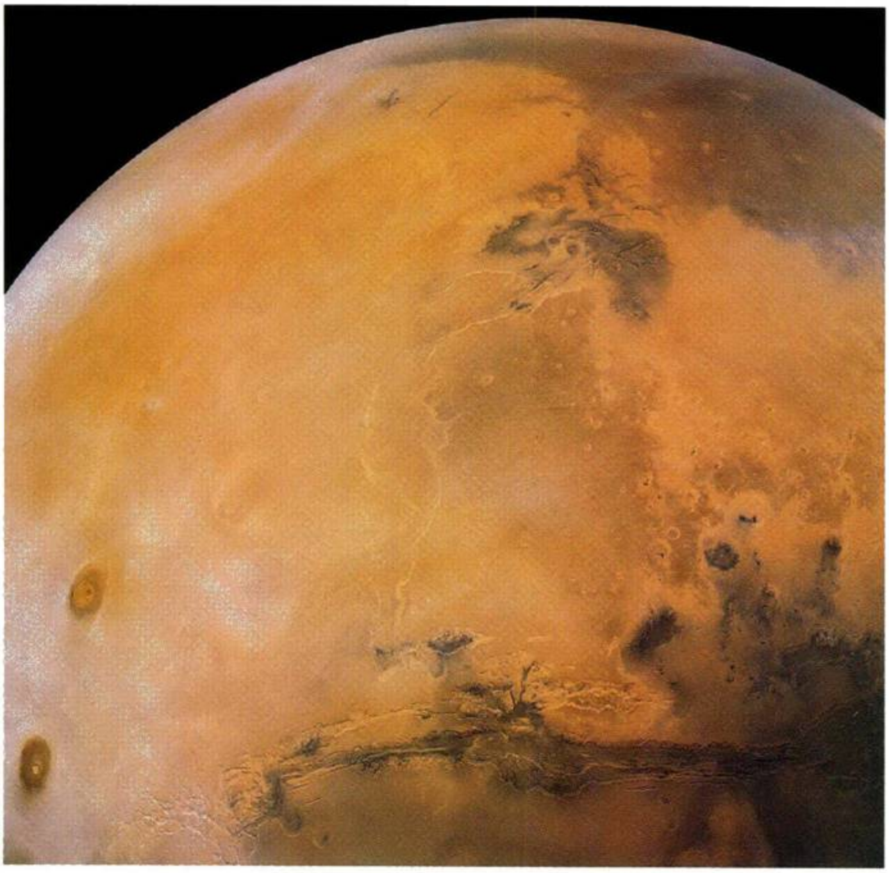
NASA/Johnson Space Center

Apollo 15 astronauts Jim Irwin (seen here) and David Scott used this rover to take a joy ride across the lunar surface. Mount Hadley lies in the background.

The moon's origin was a mystery until recently. The early solar system was a violent place, with bodies crashing into one another, leaving craters still evident on most worlds today. Astronomers think that about 4.5 billion years ago, a Mars-sized body slammed into Earth. Mantle material was blasted into orbit, where it eventually coalesced into the moon.

As happened on other young worlds, the heaviest minerals sank, so the lunar crust was composed of lightweight minerals. About 3.9 billion

Neptune
Pluto when it's closest to the sun
Kuiper Belt
Pluto when it's farthest from the sun


NASA/JPL

Valles Marineris stretches for 3,000 miles across the ruddy plains of Mars.

years ago, heat from radioactivity melted a layer beneath the surface. Large meteor impacts fractured the crust, allowing molten lava, made of darker material, to flow onto the surface, forming the maria (Latin for "oceans") — the dark patches we see on the face of the moon. Ironically, the side of the moon that always faces away from Earth has almost no maria — presumably because the crust is thicker on that side, meaning the meteor impacts weren't able to fracture it. The magma slowly cooled over the next few hundred million years, and the airless world has been dead ever since. The only changes come from the continual bombardment of meteors, which range in size from tiny specks to the mile-wide asteroids.

Scientists announced in December 1996 that they found what might be a lake's worth of ice mixed with rock in craters at the moon's south pole, where no sunlight penetrates the shadows. The water probably came from comets that collided with the moon. Because the bottom of these craters lie in perpetual shadow, the water never boiled off in the harsh lunar sunlight. If this finding is confirmed (recent observations call the finding into question), the water may someday be an important resource for lunar colonists.

Mars and Asteroids

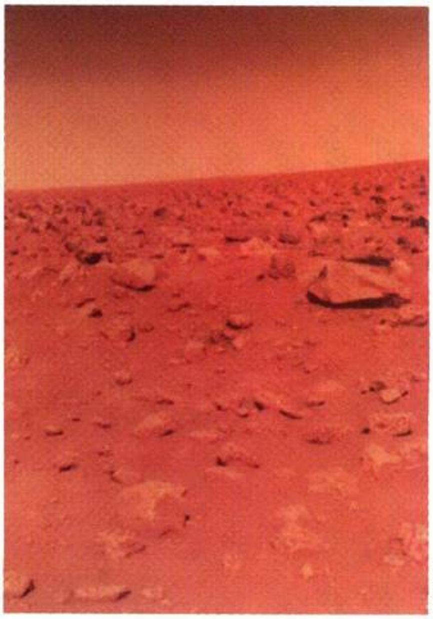
Of all the planets, Mars probably holds the most fascination for us earthlings. Astronomer Percival Lowell thought he saw artificial canals crisscrossing the surface, and writers from H. G. Wells to Ray Bradbury have depicted vastly old and wise races slowly dying in strange, spired cities. In fact, the Red Planet has so far yielded no proof of extraterrestrial life. The twin Viking landers in the 1970s were unable to find any definitive sign of life in the rusty martian soil. However, scientists have found microscopic structures within a 4-billion-year-old martian rock that might be the fossilized remains of ancient microbes.

Mars is about half the size of Earth, with a diameter of 4,207 miles (about the distance between New York and Berlin), and its mass is about one-ninth that of Earth's. You would weigh 38 percent of your Earth weight if you stood on Mars. The Red Planet orbits the sun at 1.52 AU. Despite surface temperatures that range from –225° F to 60° F (–143° C to 16° C), the carbon dioxide atmosphere is so thin (the surface pressure is only 1⁄170 the pressure on Earth at sea level) that liquid water instantly evaporates. Mars's axis of rotation is tilted 25°, almost the same as Earth's 23.45°, so Mars goes through four seasons too, as evidenced by the polar ice caps that grow and recede. A martian day is just 41 minutes longer than an Earth day, but the year is nearly double, 687 days. There is enough water vapor that fog and thin, icy clouds can form, and there might be more water locked under the surface in a layer of permafrost.

Mars is a small planet, but it has features that dwarf their terrestrial counterparts. Olympus Mons, whose base would cover the entire state of Missouri, rises three times as high as Mt. Everest. It would take eons for something to grow to that size, so Mars probably lacks plate motions that would otherwise reshape the surface. The huge trench Valles Marineris stretches for 3,000 miles and goes down four miles, making the Grand Canyon look like a paper cut in comparison.

Lowell may have been right about a slowly dying, drying planet; although his timing was off by a few billion years. Orbiting spacecraft photographed

Iron oxide molecules give Mars its reddish surface and skies. The Viking 2 lander took this image in 1976.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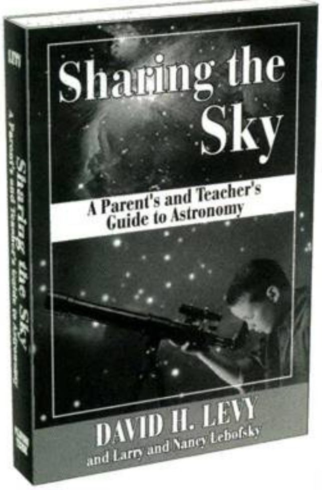
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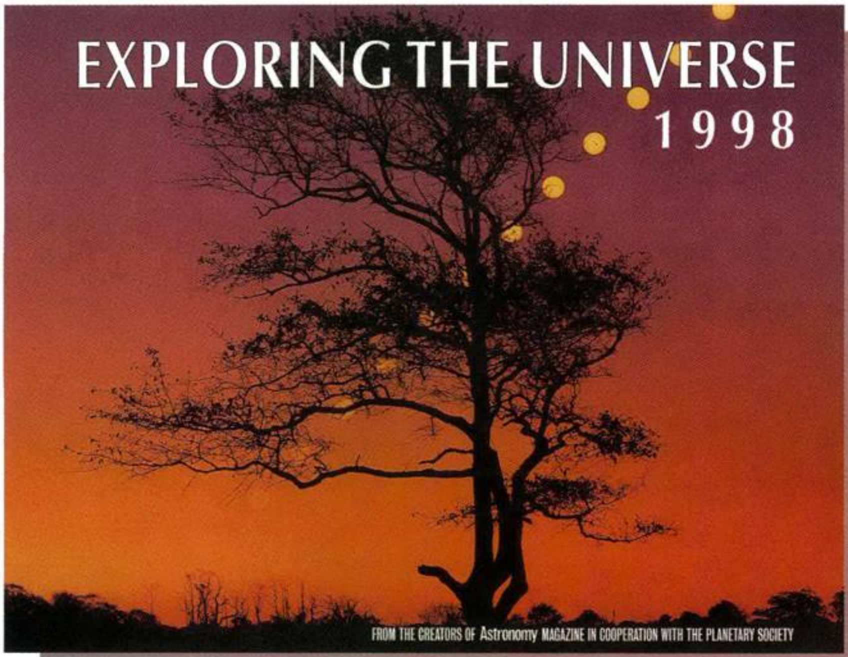
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channels that look like they were formed by flowing water eons ago. The ancient martian climate must have been warmer and wetter. It's possible that microbial life evolved under those fairer conditions, then retreated underground as the lower gravity allowed the atmosphere to leak away into space.

Mars has two small satellites that are best described as dark, heavily cratered, giant boulders. The inner moon Phobos spans 17 by 13 by 12 miles and orbits a mere 5,827 miles from its parent. At that distance, it whips around the planet every 7.7 hours. Deimos measures 9 by 7.4 by 7 miles and orbits 14,577 miles away. The diminutive moons may once have been part of the asteroid belt, and strayed close enough for Mars's gravity to reel them in.

The asteroid belt lies in the vast expanse between Mars and Jupiter. Thousands of bodies orbit here, from tiny grains of sand to Ceres, a body 580 miles across (roughly the distance from Detroit to Des Moines). All the material in the asteroid belt put together would make a body much smaller than Earth's moon. If you saw *The Empire Strikes Back*, you might envision the asteroid belt as a dense swarm of rocks bouncing off one another and smashing into unwary spaceships. In fact, the asteroid belt is mostly empty space. Jupiter's massive gravity prevented the bodies in the asteroid belt from aggregating into planet-size objects; sending some flying away from one another and others smashing together so fast they shattered into smaller bits.

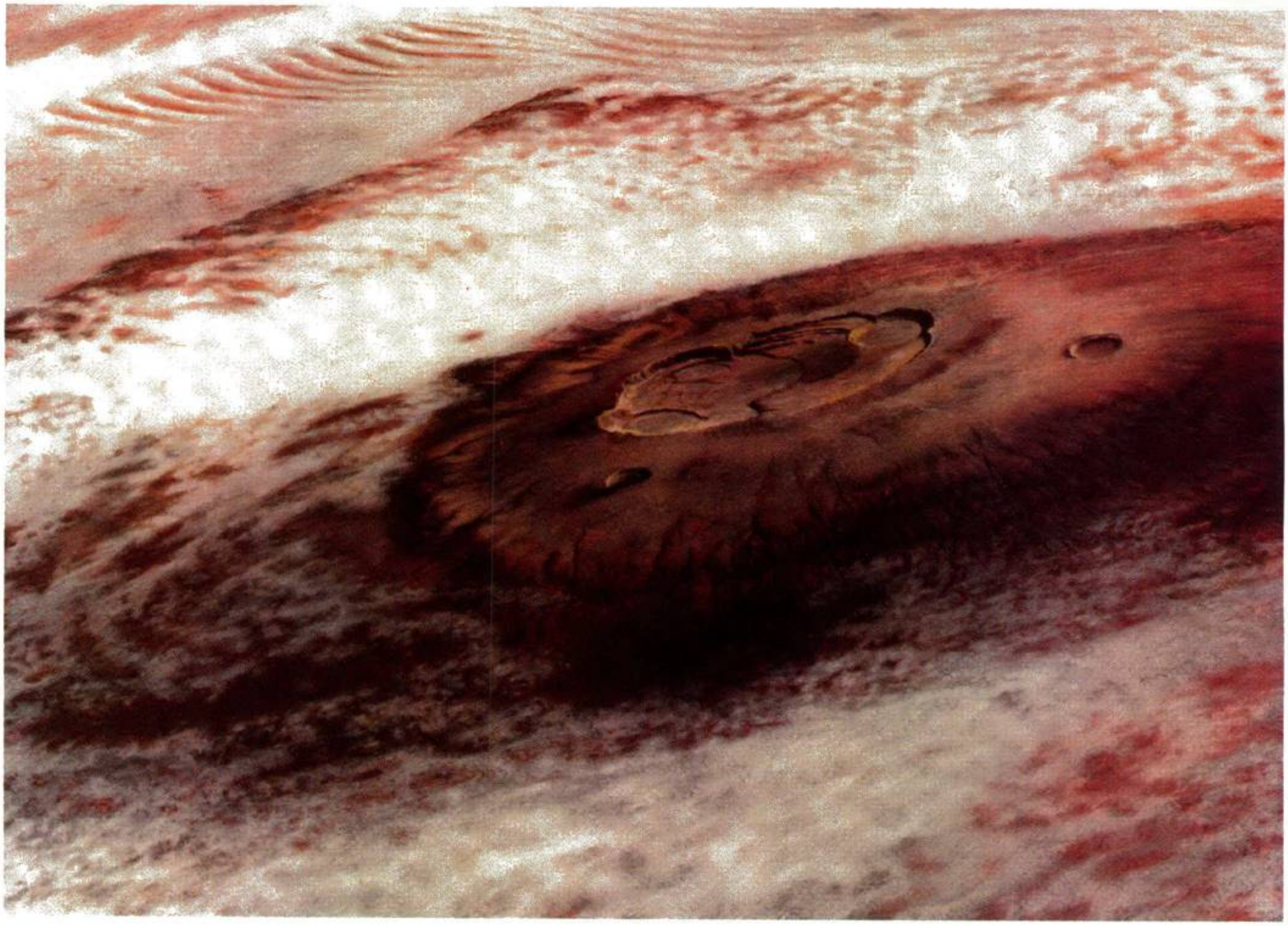
Tiny Gaspra, 12 by 7.5 by 7 miles, became the first asteroid to be studied up close when the Galileo spacecraft flew by it in 1991. It looks like a broken piece of a larger body, and it may have existed in its current state for only a few hundred million years. Ida, also photographed by Galileo, is 3.5 times longer than Gaspra. Ida has a 1-mile-wide satellite called Dactyl.

Not all asteroids remain confined to the main belt. Certain asteroids, the Amors, cross the orbit of Mars, and others, the Apollos, cross Earth's orbit. The tug from the planets can change the asteroids' orbits. Some are destined to hit Earth or one of the other planets. Earth gains 100 tons per year in space debris (mostly dust). Most scientists agree the dinosaurs died when an asteroid slammed into the Yucatán Peninsula 65 million years ago, igniting worldwide fires and throwing up clouds of ash that blotted out the sun for years.

The Jovian System

Farther from the sun, we move into the realm of the gas giants. Jupiter orbits the sun at 5.2 AU, equivalent to half a billion miles. At that distance, Jupiter only receives 1/27 as much sunlight as does Earth, so temperatures at Jupiter's cloudtops are a rather frigid –235° F (–150° C). A Jupiter year lasts 11.9 Earth years.

Jupiter is named for the king of the Roman gods. And while the Romans didn't know it at the time, the name couldn't be more appropriate. With a diameter of 88,850 miles, you could fit



The giant volcano Olympus Mons towers over the martian landscape. The white clouds contain water vapor.

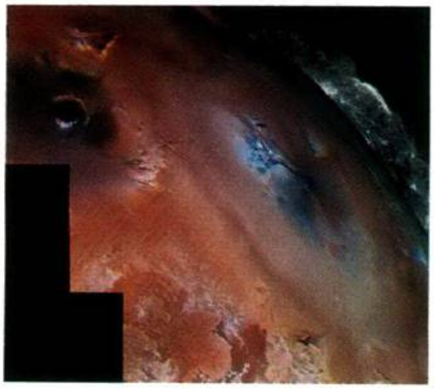
NASA/JPL

more than 1,000 Earths inside Jupiter. With a mass of 318 Earths, Jupiter contains 2.5 times the material of all the other planets combined. If you could stand on Jupiter's cloudtops, you would weigh 2.3 times your Earth weight — a definite incentive to go on a diet. Jupiter still retains heat left over from its formation. It radiates almost twice as much energy as it receives from the sun, making it one of the brightest radio sources in the sky.

At the center of the planet lies a rock and ice core the size of Earth (but about 15 times more massive), which is surrounded by a 25,000-mile-wide layer of liquid metallic hydrogen. Jupiter's day goes by in only 9.9 hours. As the planet whirls around its axis, the spinning of the metallic hydrogen generates the planet's enormous magnetic field, which is 20,000 times stronger than Earth's. The metallic hydrogen layer gradually thins until it fades into the hydrogen and helium atmosphere. The planet's rapid rotation whips the upper cloud layers, which contain methane, ammonia, and water, into the familiar counterflowing bands that can be seen even in modest backyard telescopes. The Great Red Spot, a giant anticyclone that could easily swallow Earth whole, has been spinning ever since British scientist Robert Hooke first spotted it in 1664.

In July 1993 the planet provided an example of the aerial bombardment so common in the early days of the solar system. The 21 fragments of Comet Shoemaker-Levy 9, torn asunder by Jupiter's gravity, struck with a force far greater than humanity's entire nuclear arsenal, leaving behind a series of Earth-sized black stains on the cloudtops. These black marks have since disappeared without a trace, erased by Jupiter's 500-mile-per-hour winds.

Jupiter's moon Io is the most volcanically active body in the solar system. It is literally turning itself inside-out.



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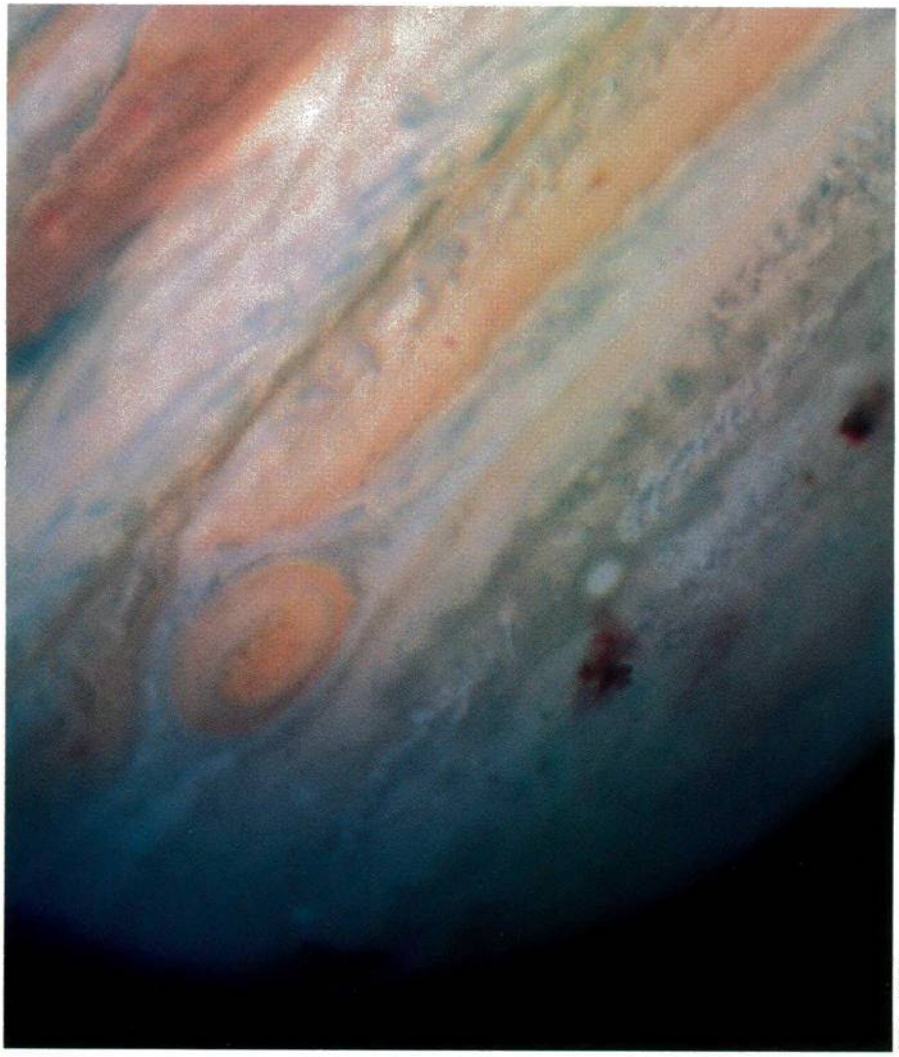


STScI and NASA

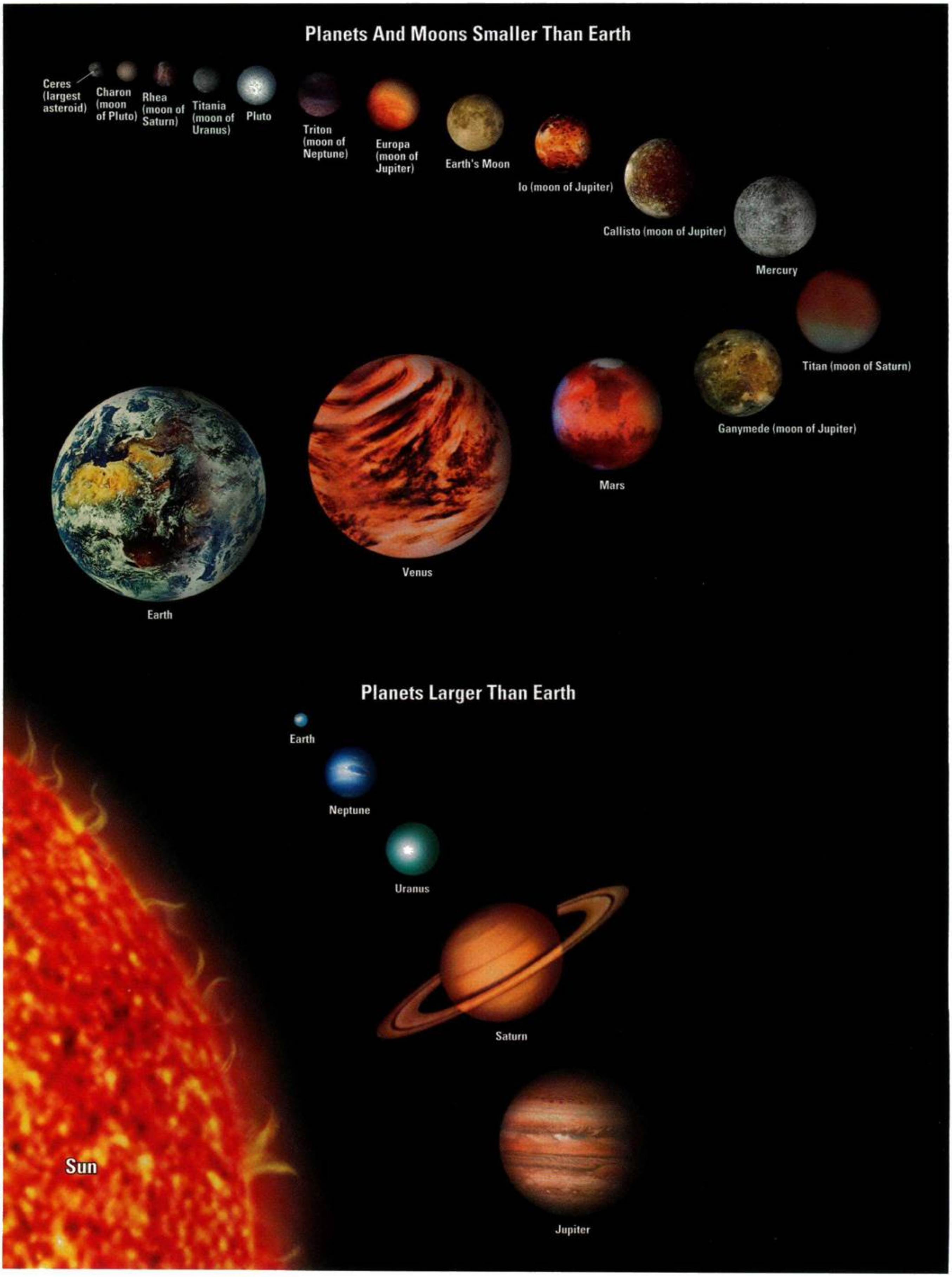
Jupiter's dark splotches – about the size of Earth – bear witness to the impact of Comet Shoemaker-Levy 9.

Jupiter has been likened to a solar system in miniature. The planet itself is similar in composition to the sun, but it's not nearly massive enough to light the nuclear spark that makes the sun shine. The planet has a thin ring and its own extensive system of 16 satellites. The four largest moons were discovered in 1610 by the great Italian astronomer Galileo Galilei, and hence are called the Galilean satellites.

The outermost of these moons is Callisto, the second largest jovian moon and the third largest in the solar system. An icy body covered with carbonaceous rock, Callisto is 2,980 miles in diameter and orbits Jupiter every 16.7 days at a distance almost five times the Earth-moon distance. Once thought to be geologically inactive, high resolution images from the Galileo spacecraft show that it is pockmarked with many large impact craters but few small ones. Some unknown process must be erasing the small craters.

Next in from Callisto is Ganymede. At 3,270 miles in diameter, it is the largest moon in the solar system, and it's even bigger than two planets: Mercury and Pluto. Unlike most satellites, Ganymede has a fairly substantial magnetic field. Readings taken by Galileo in 1996 suggest there may be salty water beneath its icy surface. It even has a tenuous ozone atmosphere, the result of radiation from Jupiter interacting with surface ice.

The next moon in, Europa, is a giant ice ball. A latticework of ridges and grooves decorates its otherwise featureless surface. With a diameter of 1,950 miles, Europa is slightly smaller than Earth's moon. Jupiter and the other Galilean satellites raise tides on Europa, which squeeze and flex the



Planets And Moons Smaller Than Earth

Ceres (largest asteroid)
Charon (moon of Pluto)
Rhea (moon of Saturn)
Titania (moon of Uranus)
Pluto
Triton (moon of Neptune)
Europa (moon of Jupiter)
Earth's Moon
Io (moon of Jupiter)
Callisto (moon of Jupiter)
Mercury
Titan (moon of Saturn)
Ganymede (moon of Jupiter)
Mars
Venus
Earth

Planets Larger Than Earth

Earth
Neptune
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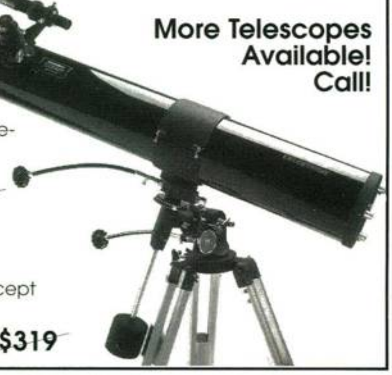

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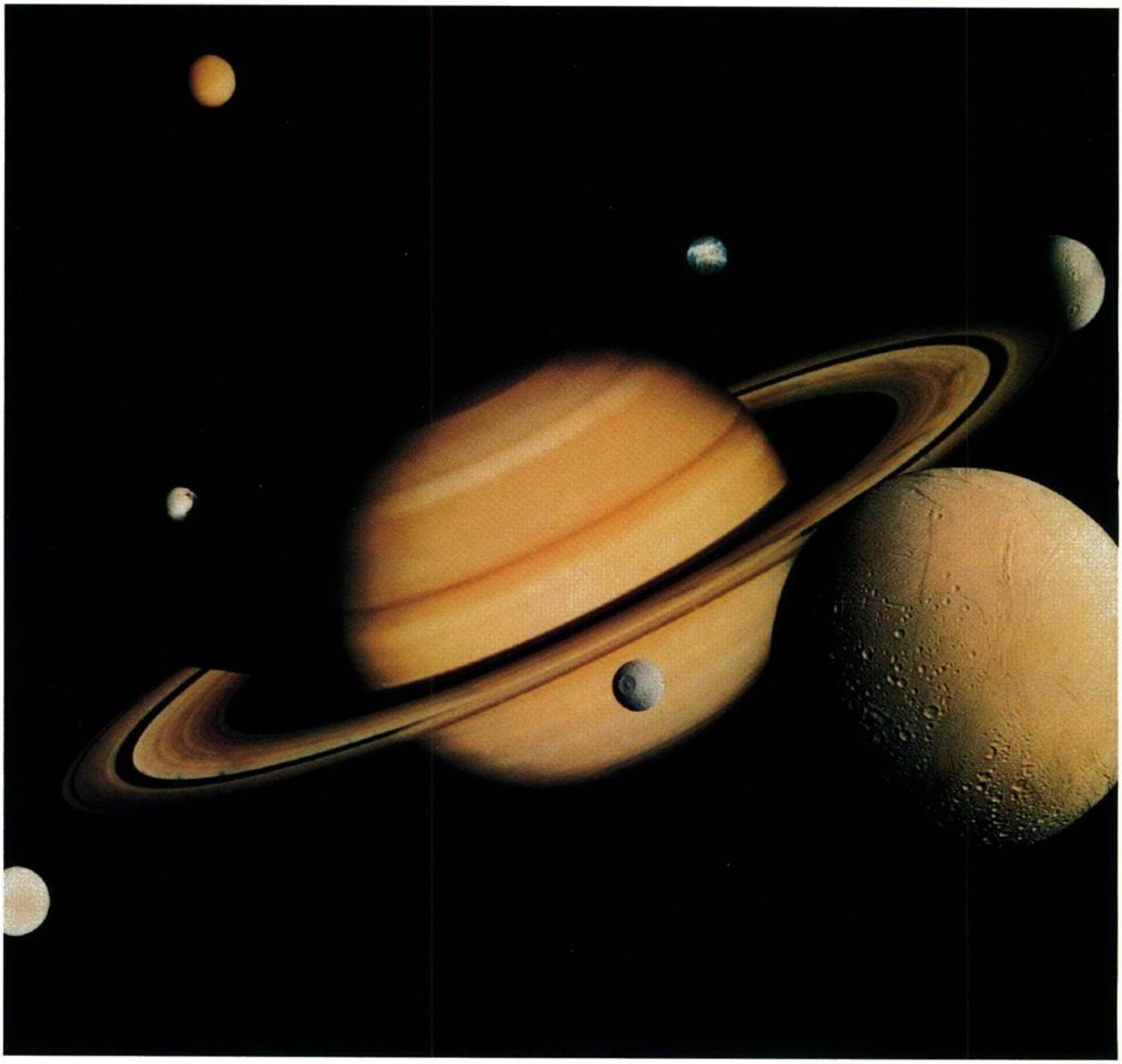

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moon — heating its interior. Scientists have speculated that Europa could have a subsurface ocean 10 miles thick or more. The Galileo spacecraft has imaged surface features that look like they have been covered by liquid water oozing from below, just as molten lava sometimes comes to the surface on Earth. This is one place in the solar system scientists will definitely be looking for signs of life.

If Jupiter and the other satellites are rough on Europa, consider poor Io, only 260,000 miles away from the giant (that's just a tad farther than the Earth-moon distance). But this 2,256-mile-wide moon (just a shade larger than Earth's moon) is made of rock rather than ice. Instead of liquid water, Io spews liquid sulfur with such ferocity that it is by far the most volcanically active body in the solar system. Io continually resurfaces itself, which explains why there are no large impact craters on its multi-colored surface.

As Io races around Jupiter every 1.8 days, it gives off a yellow haze of sulfur particles. These particles rain down on Jupiter, and on the four tiny moons in lower orbits. The largest of these tiny worlds is football-shaped Amalthea, only 167 by 105 by 96 miles across. This world is so small that gravity can't pull it into a sphere. Farther in, where Jupiter's gravity would tear a moon to pieces, lies a thin ring, made up of particles about the size of those that float away from a burning cigarette.

The saturnian system is a mini-solar system, consisting of a giant planet, rings, and at least 18 moons.

Saturn

Saturn, the second largest planet, is a scaled-down version of Jupiter. The two gas giants share a similar internal structure and chemical composition. Saturn, however, is considerably smaller than its giant sibling. Saturn's diameter is 84 percent that of Jupiter and with a mass of 95 Earths, the ringed planet is only one-third as massive as the king. Saturn produces its own internal heat, but its storm systems are far less active than Jupiter's. With an orbit of 9.5 AU, almost twice the distance of Jupiter, it has a year of 29.5 Earth years. Like Jupiter, it has a short day, which lasts only 10.7 hours. Saturn is the least dense planet, with a density only 70 percent that of water (it would float if you could find a big enough bathtub). Because of its low density and rapid rotation, Saturn is more oblate than any other planet. You can tell that Saturn is not a perfect sphere even when viewing it through a small telescope.

All the giant planets have rings, but none match the splendor of Saturn's. These rings have a diameter of 170,000 miles, which would fill two-thirds the distance between Earth and the moon. But the rings are only about half a mile thick, meaning a scale model covering a city block would have the thickness of a sheet of paper. Most of the ring particles are either made of ice or are coated with ice, and they range in size from dust particles to house-sized boulders. Most of the particles are similar in size and composition to snowballs. There are actually thousands of rings, the inner ones orbiting much faster than the outer. If you put all the material together, you'd get a moon only 150 miles in diameter. But the ring particles will never coalesce into a moon because Saturn's tidal forces would tear any close-in moon to shreds.

Saturn also has its own retinue of 18 moons, including Titan, the second largest moon in the solar system with a diameter of 3,200 miles (which makes it slightly larger than Mercury). Titan orbits Saturn every 16 days at a distance of 760,000 miles — three times the Earth-moon distance. Unlike any other moon in the solar system, Titan has a thick atmosphere; Voyager 1 measured a surface pressure 1.6 times the pressure at sea level on Earth. Titan's atmosphere is primarily nitrogen, like Earth's atmosphere, but instead of oxygen and carbon dioxide making up the rest of the atmosphere, Titan's air holds such noxious vapors as methane, ethane, and hydrogen cyanide. The surface temperature hovers around –290° F (–180° C, or just 93° C above absolute zero), probably making it too cold to support life. But there could be some sort of prebiotic chemistry going on. We'll learn a lot more about Titan in 2004 when the Cassini spacecraft drops off the Huygens lander.

The most distant moon is 137-mile-wide Phoebe, circling Saturn every 550 Earth days in a retrograde orbit, clockwise when viewed from above the north pole instead of the counterclockwise direction in which most satellites move. Dust knocked off Phoebe by the impact of meteorites may spiral inward to the next moon, Iapetus (907 miles in diameter), just as Io's sulfur dust drifts down to Amalthea. This could explain why Iapetus's leading hemisphere is as dark as charcoal while the trailing hemisphere is as bright as ice.

Between Iapetus and Titan lies Hyperion, an oblong ice world with a long axis of 255 miles. Inside Titan come three medium-sized ice moons: Rhea (950 miles across), Dione (695 miles), and Tethys (653 miles). Closer in is Enceladus (312 miles). Enceladus has fewer impacts than the other satellites, and its icy surface is the most reflective of any major body in the solar system. Astronomers have speculated that Enceladus may have water geysers, a view bolstered by the fact that a thin ring of tiny particles orbits Saturn at the same distance as Enceladus. Mimas, with a diameter of only 245 miles, is the closest of the major saturnian satellites. Mimas has a circular 81-mile-wide crater that gives the diminutive moon the appearance of the Death Star in the *Star Wars* movies. If the impacting object that formed this crater were slightly larger, Mimas would have been blown to bits. The rings and half a dozen tiny moons lie inside Mimas.

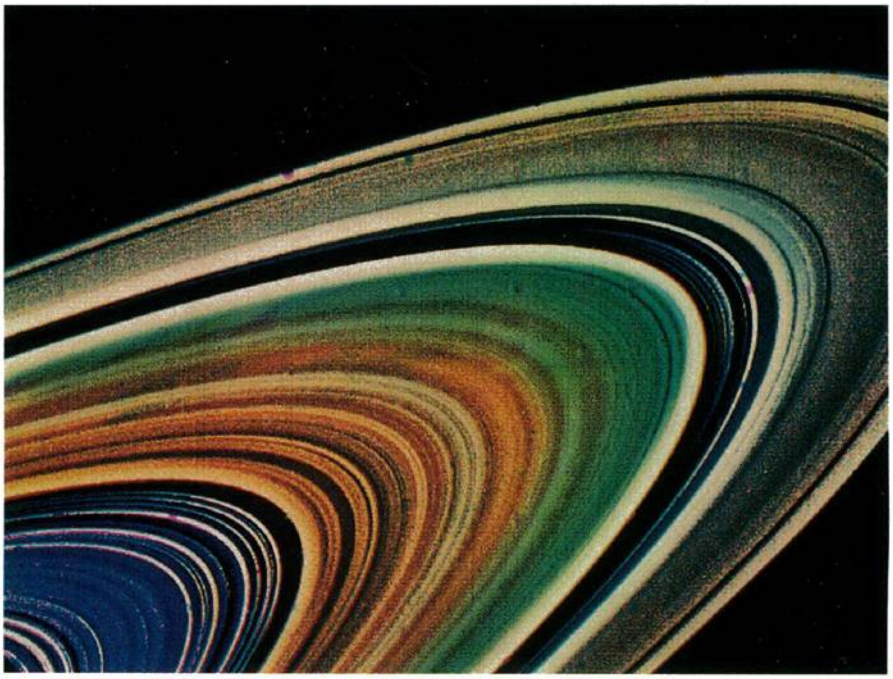
Uranus and Neptune

You have to more than double your journey from the sun to Saturn to reach Uranus, at 19.2 AU. Compared to Jupiter and Saturn, Uranus is a relatively serene blue planet with a slushy mantle and a hydrogen-methane atmosphere. It's a much smaller giant, with a diameter of 31,765 miles, four times Earth's, and a mass 14.5 times that of our planet.

Probably the most unusual thing about Uranus is its orientation. Most of the planets rotate around an axis nearly perpendicular to the plane of the solar system. But Uranus's axis lies almost directly in the solar system's plane. It is, in essence, lying on its side and rolling along its orbit. A mini-planet probably smashed into Uranus sometime in the distant past, as if a child had kicked a spinning top.

Right now, the planet's south pole is aimed at the sun, while the north pole remains in perpetual darkness. But as Uranus chugs along its 84-year orbit, the sun will eventually hover over the equator, so the entire planet will be lit

This false-color Voyager image shows that Saturn's ring system consists of thousands of individual rings. The material in the rings will never coalesce into a moon.

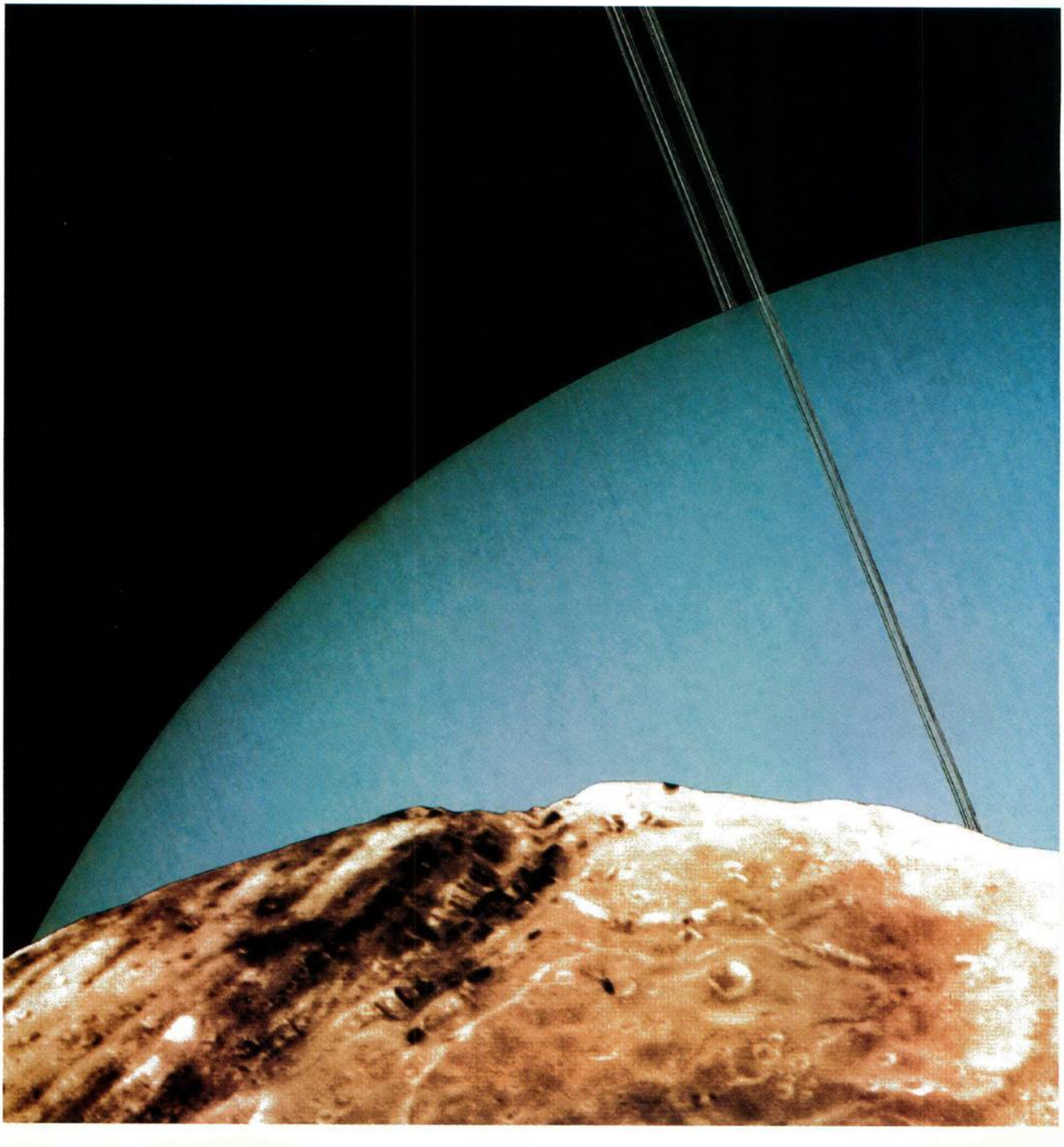


NASA/JPL

sometime during its 17.2-hour day. Once it has traveled another quarter of the way around, the south pole will receive all the sunlight. Astronomers who study planetary atmospheres are eager to see what changes the move from winter to summer will bring.

Uranus possesses a small ring system, 10 small moons that orbit close to the planet and are only a few dozen miles across, and five medium-sized moons farther out. The four largest moons — Oberon, Titania, Umbriel, and Ariel — are quite similar to one another, ranging in size from 720 to 982 miles in diameter (all are less than half the size of Earth's moon). These moons have heavily cratered surfaces that are a mixture of ice and rock. The innermost medium-sized moon is Miranda, which has a strange, jumbled surface with towering cliffs, fractures, grooves, and racetrack-shaped features. Because the mass of Uranus attracts approaching meteorites and comets, Miranda, at a distance of only 81,000 miles from the planet, stands a better chance of being battered than its larger and more distant siblings. In fact, scientists think poor Miranda, being only 298 miles across, might have been smashed to bits, then slowly reassembled by gravity.

This composite image from Voyager 2 shows Uranus hovering over its small moon Miranda.



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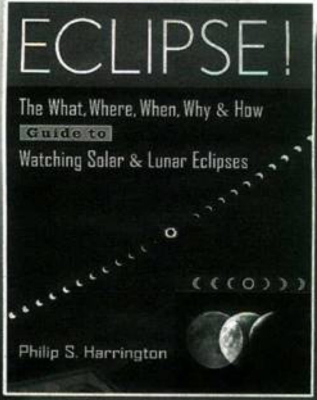
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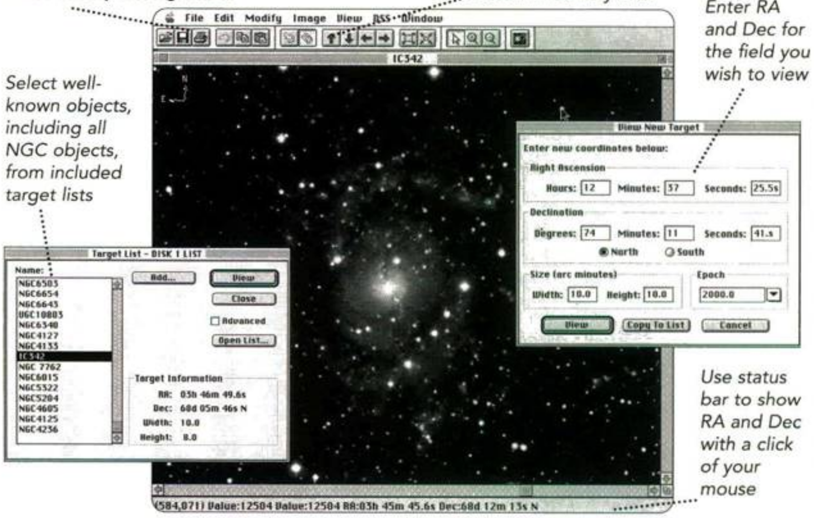
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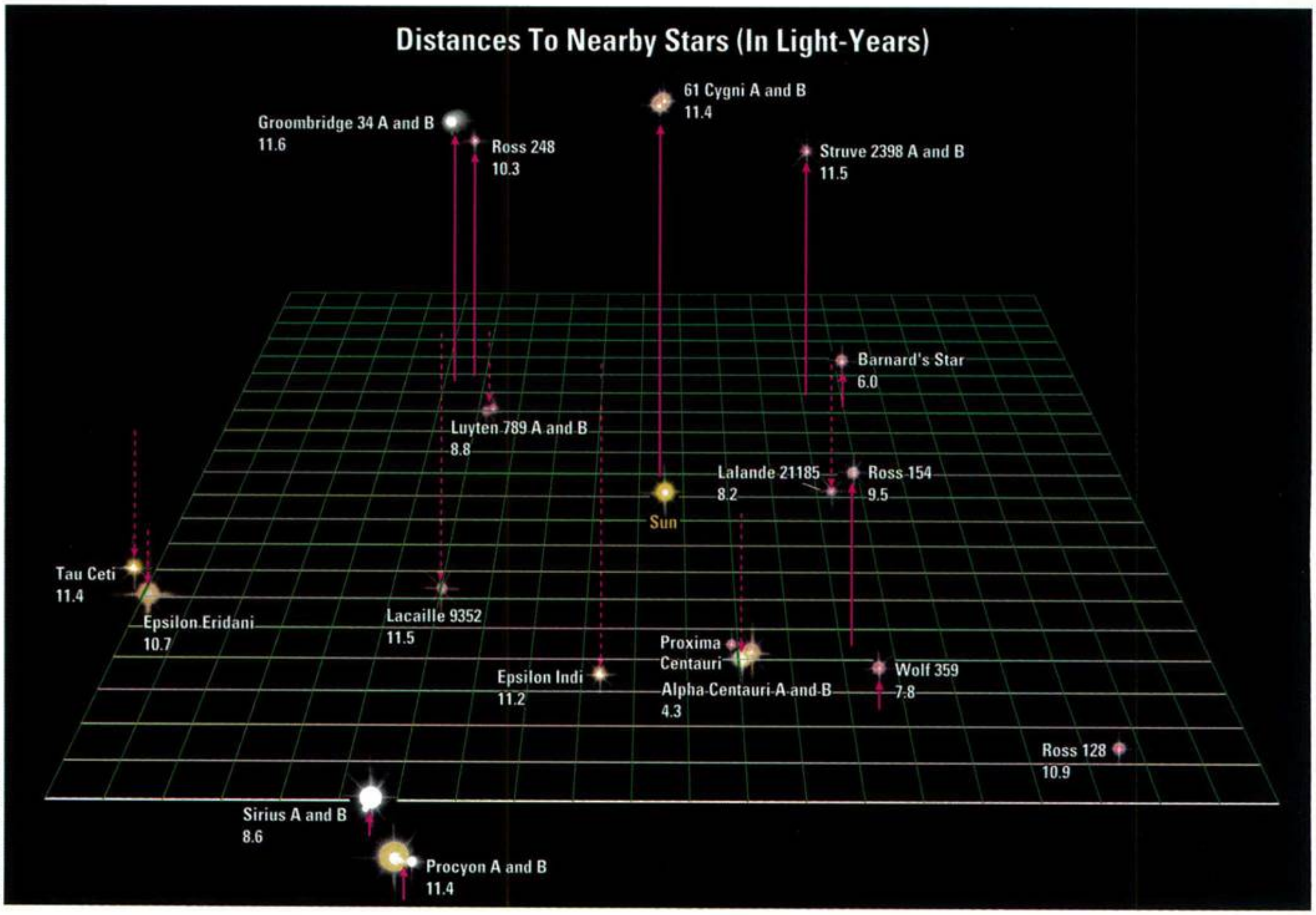


Astronomy: Elisabeth Rowan

Quick quiz. What is the most distant planet in the solar system right now? Bzzz! Wrong! Thank you for playing. The planet farthest from the sun is Neptune, at least for the moment. Pluto slipped inside Neptune's orbit in 1979, and it will cross back in 1999.

At 30 AU, Neptune orbits as far from Uranus as Uranus does from Saturn. With roughly the same size, mass, density, chemical composition, and internal structure, Uranus and Neptune are probably more similar to each other than any other pair of planets in the solar system. Like Uranus, the methane in Neptune's atmosphere absorbs the red light of the sun and reflects the blue. Unlike Uranus, however, the weather on Neptune is very active. In 1989, Voyager 2 flew past Neptune and discovered a huge dark blue storm system swirling in the southern hemisphere — a storm system about the size of Earth. Since it looked like Jupiter's Great Red Spot, astronomers christened it the Great Dark Spot. Perhaps it, too, had been spinning for centuries. Imagine their surprise when, in 1994, they pointed the Hubble Space Telescope at the planet and found the spot had vanished, only to be replaced by another spot in the northern hemisphere. That spot has since faded somewhat, but at last check was still visible. Neptune receives only 1/900 as much sunlight as Earth does, so internal heat must be driving Neptune's weather.

Neptune has one large moon, Triton, which distinguishes itself from the competition by the fact that it is the largest object in the solar system to orbit in a clockwise direction as seen from the north of the solar system. With a diameter of 1,680 miles, it is slightly smaller than our moon. And while most moons orbit their primaries above the equator, Triton circles Neptune at a 23° tilt, going around every 5.9 days at a distance of 220,000 miles. It must have formed elsewhere in the solar system and been captured by Neptune, winding up in a retrograde orbit by sheer chance. Triton has a thin nitrogen-dominated atmosphere, which produces a surface pressure just 1/100,000 that of Earth's. There are few craters, but the Voyager 2 spacecraft, during its 1986 flyby, imaged what appear to be nitrogen-spouting geysers and frozen lakes of water ice.

Neptune has seven small satellites, ranging in size from 40 to 270 miles in diameter. Like the other gas giants, Neptune has rings — four dark and narrow bands of dust around the planet. The outer ring has three sections where the particles bunch up into short arcs, probably due to the gravitational influence of nearby moons. The ring material will never form a moon.

Pluto and the Outer Solar System

Pluto, with an average distance of 39.5 AU, stands out in many respects. It's the only planet discovered this century, in 1930 by Clyde Tombaugh. It's also by far the smallest planet, with a diameter of only 1,430 miles (that's less than the distance from Philadelphia to Dallas). Pluto takes 248 years to travel around the sun in an eccentric orbit, which is inclined 17° to the plane of the solar system. It has a special orbital relationship with Neptune called a "resonance": Pluto goes around the sun twice every time Neptune goes around three times. Astronomers don't think this is a mere coincidence.

If you thought our moon was big in comparison with Earth, consider Pluto's moon Charon. With a diameter of roughly 740 miles, it's about half the diameter of Pluto. If anything in the solar system qualifies as a double planet, it's the Pluto-Charon pair, which circle each other every 6.4 days.

Both worlds are icy, but Charon is darker, probably because it is smaller and has less gravity. Methane ice escapes from Charon's surface more easily, and rains down on heavier Pluto, where it reflects more light than the rock left behind. Recent Hubble Space Telescope observations show that Pluto has more light-dark contrast than any other planet or moon in the solar system. Pluto has a very tenuous nitrogen-methane atmosphere, which freezes out onto the surface when Pluto's eccentric orbit takes it farther away from the sun.

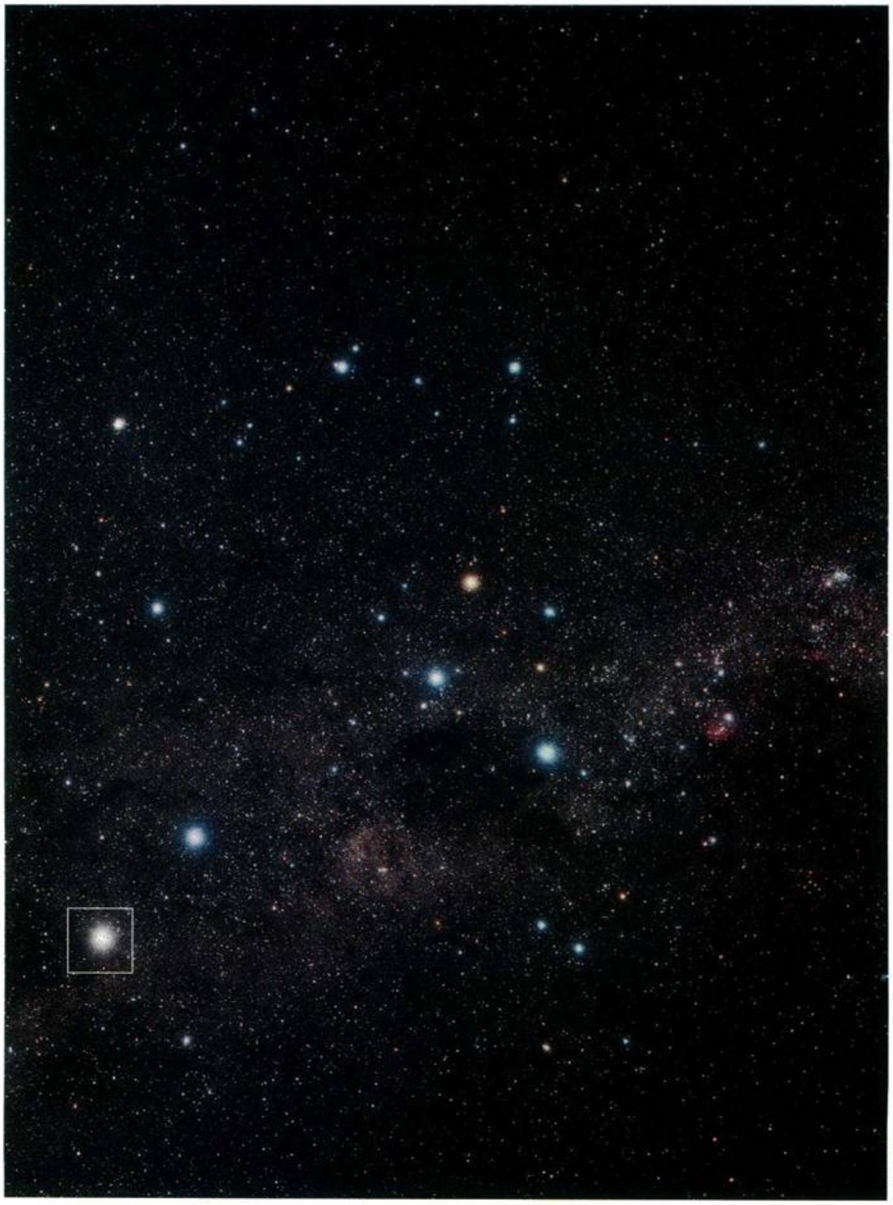
Pluto and Charon were probably part of the same body that was smashed apart during an impact. In fact, the pair represents a new major class of bodies that formed from leftover debris in the outer solar system: ice dwarfs. Triton probably originated in the realm beyond Neptune before being captured. Astronomers also think that Chiron (a giant comet about 160 miles across), and six other small bodies that orbit between Saturn and Neptune, originated way out there.

Pluto, even when it lies beyond Neptune, doesn't mark the outer edge of the solar system. In 1992, astronomers David Jewitt and Jane Luu found the first body in the until-then theoretical Kuiper Belt, which consists of ice dwarfs that orbit the sun from just beyond Pluto's orbit out to at least 150 AU. About 40 Kuiper Belt objects have been detected, but they're hard to see because they're far away, tiny, and dark. Astronomers estimate that there are 40,000 to 70,000 Kuiper Belt objects at least 60 miles wide and billions that are at least one mile wide. The asteroid belt, by comparison, holds only about 230 bodies that are 60 miles in diameter or larger.

Some Kuiper Belt objects, tugged by the gravity of the giant planets, have ventured closer to the sun on occasion. The Kuiper Belt is the source of most short-period comets, anything that dives close to the sun in an orbit of less that 200 years. The most famous of these, of course, is Halley's Comet, named for the British scientist Edmond Halley, who determined that the comets of 1531, 1607, and 1682 were one in the same. Halley's Comet follows a long elliptical orbit, looping around the sun every 76 years.

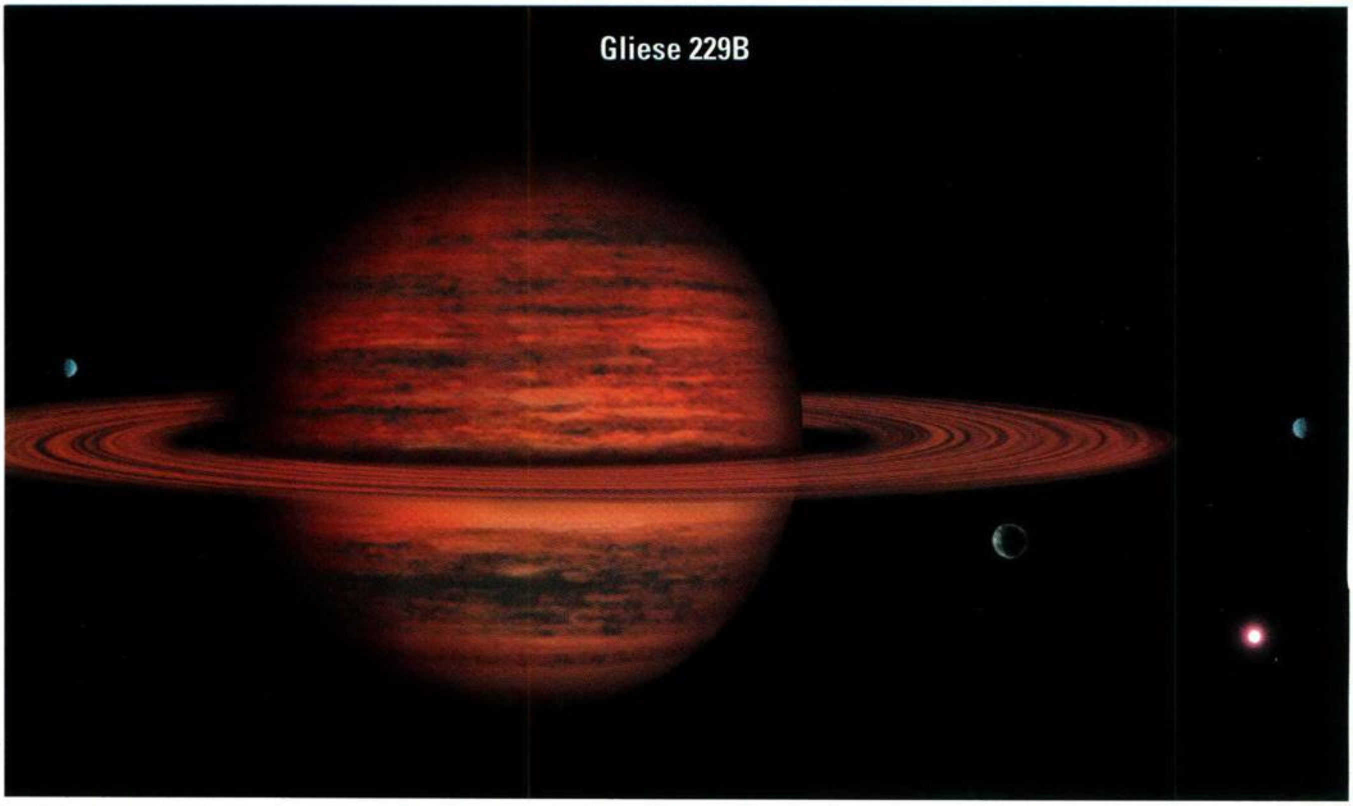
Comets are aggregates of ice and rock. As they move inside Jupiter's orbit, solar heating thaws some of the ice, which forms a cloud around the nucleus called the coma. The pressure of sunlight and the solar wind pushes coma material in the direction opposite the sun, forming the tail. A comet's tail always streams away from the sun regardless of the direction of the comet. After enough orbits, all the ice and dust is blown away, and the comet becomes a dead, dark rock.

Skywatchers have recently been treated to two spectacular comets: Hyakutake in 1996 and Hale-Bopp in 1997. With long-period orbits of 16,000 and 2,400 years respectively, these comets didn't originate in the Kuiper Belt. Back when the solar system was more crowded, small objects frequently smashed into planets. But the gravity of the giant planets flung trillions of leftover bodies away from the inner system. Most of the bodies were launched out of the solar system; these bodies now wander the galaxy as interstellar comets. But billions of other



Luke Dodd

Alpha Centauri (boxed) is the closest star system to the sun. Proxima lies 2° southwest of Alpha Centauri.



Astronomy: Elisabeth Rowan

The brown dwarf Gliese 229B, shown here with hypothetical rings and moons, is more massive than a planet. But it's not massive enough to ignite like a star.

bodies remained loosely bound to the sun in the Oort Cloud, a sphere of debris extending 50,000 AU in all directions, a fifth of the way to the nearest star. Gravity of passing stars can change their orbits. Some get knocked deeper into the solar system, where they become long-period comets. Others are tossed outward, to wander among the stars, frozen for eternity.

So where, exactly, does the solar system end? One possible dividing line is the heliopause. The solar wind blows well beyond Pluto, until it is finally overpowered by the combined winds of the other 200 billion stars in the galaxy. The heliopause could lie at 100 to 150 AU in the direction of the sun's motion around the galaxy. Scientists hope Voyager 1 will still be functioning long enough to record the boundary, which it could reach in perhaps 20 years.

The Solar Neighborhood

Now that we're out of the solar system, it's clear sailing to the next nearest star: Proxima Centauri, 4.22 light-years away. The Chevy that took 1.6 years to drive across the sun will be well past warranty by the time it reaches Proxima Centauri. It has to cover 25 *trillion* miles, or 270,000 AU. At 60 miles per hour, you'd have to drive more than 47 million years, and that's without stopping for gas, lunch, or a night's sleep. The light from your headlights, however, would get there in 4.22 years, although it would be so faint the Centaurians would never notice it.

Even though Proxima is the nearest star, you can't see it with the naked eye. That's because it's a red dwarf, only 1⁄30,000 as luminous as the sun. The sun is nine times wider and 10 times more massive than Proxima. Its surface temperature of 3,000 kelvins is only half as hot as the sun. You'd have to be within 0.006 AU of Proxima for it to seem as bright as the sun does from Earth.

So it's a conservative star, but what it loses in glory it gains in longevity. Because it burns its hydrogen fuel so slowly, it will last for a trillion years, approximately 100 times as long as the universe has existed so far. And it's got plenty of company: 70 percent of the stars in the Milky Way are red dwarfs.

If you ask people to name the sun's closest stellar neighbor, some will probably say Alpha Centauri. Alpha Centauri is actually a system of three stars, with Proxima being the smallest member. The most prominent of the three is Alpha Centauri A, a yellow star with virtually the same 6,000-kelvin temperature as the sun. It is about 10 percent more massive and 50 percent brighter than the sun. The third star is the slightly smaller and cooler Alpha Centauri B, which is about 90 percent the mass of the sun. Its 5,300-kelvin surface temperature gives it an orangish hue.

At a distance of 4.3 light-years, Alpha Centauri A and B are slightly farther away than Proxima Centauri. On average, A and B are separated by 23 AU, slightly farther than the distance between the sun and Uranus. They come as close as 11 AU as they orbit each other every 80 years. Proxima, or Alpha Centauri C, as it's also called, lies so far away from A and B that some astronomers question whether it's actually part of the same system. At 13,000 AU from A and B, it takes a million years to orbit the main pair.

Conceivably, there could be planets around either A or B, but to enjoy stable orbits, they would have to orbit within two AU of their respective stars. Life might be possible on such planets, though no one knows whether conditions would allow it to form. Proxima is so dim and cool that it seems unlikely to support life as we know it.

Most of the stars in the galaxy are binaries. Take Sirius, for instance, which is 8.6 light-years from Earth. The

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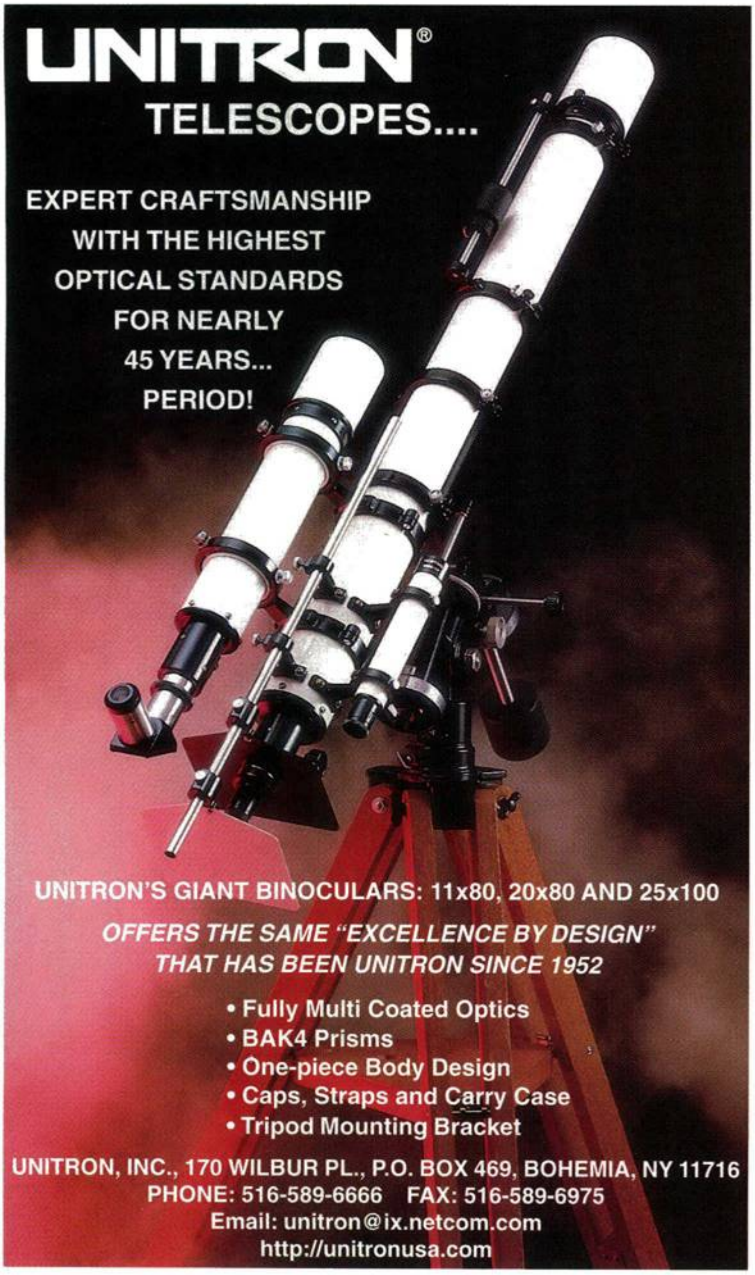

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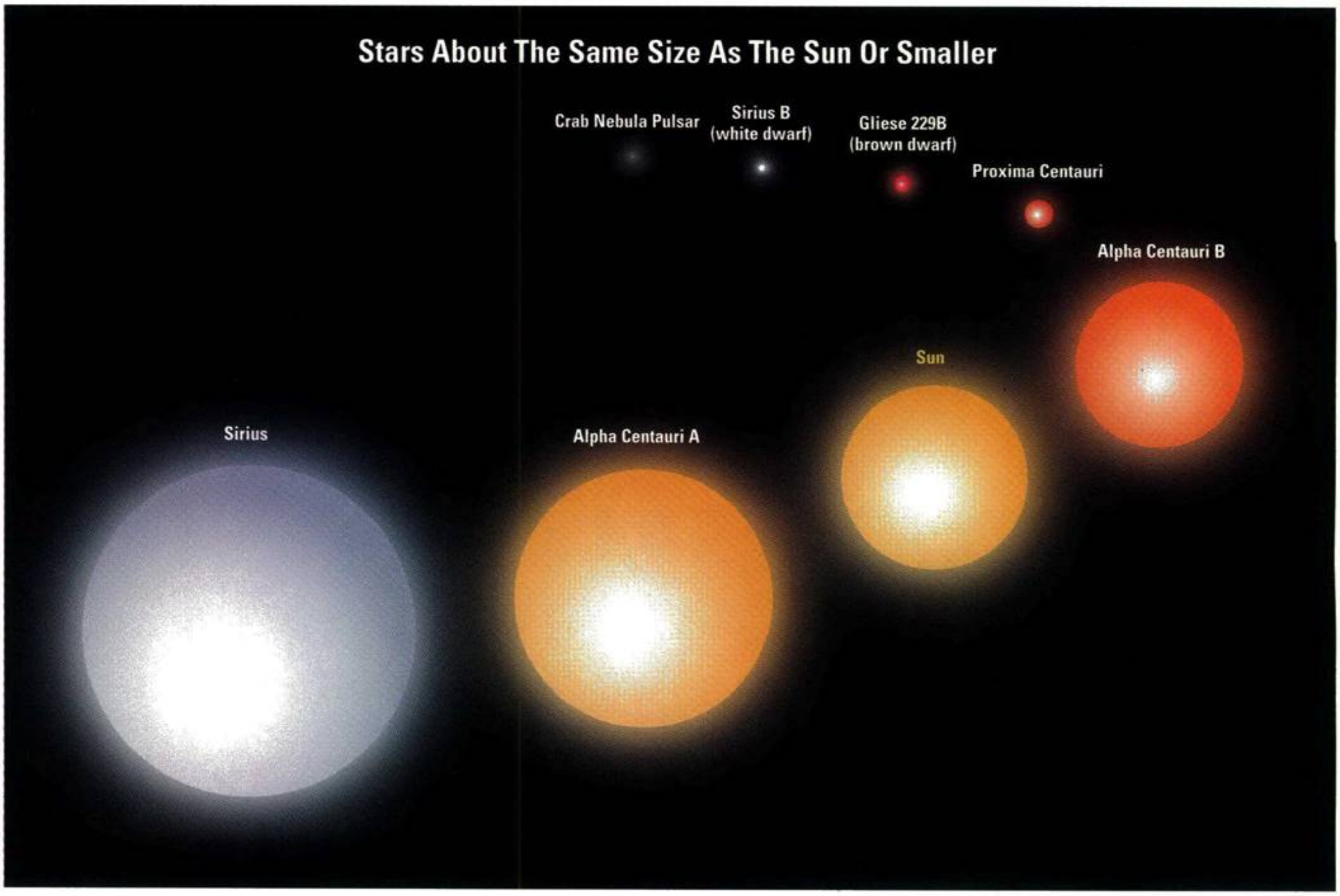


Astronomy: Elisabeth Rowan

light we're seeing today left Sirius in the early days of George Bush's presidency. The main star, Sirius A, is the brightest star in the night sky, partially because of its proximity and partially because it is 23 times more luminous than the sun. It has about 2.3 solar masses and a diameter of 1.8 suns. It's hot, 10,000 kelvins, which gives the star a white hue.

In 1834, German astronomer Friedrich Bessel noticed that Sirius did not cross the sky in a straight line. Instead, it wobbled back and forth slightly. Bessel deduced the existence of a dark companion that was tugging on Sirius. In 1862, American telescope maker Alvan Clark spotted the companion about 20 AU from the main star with his 18.5-inch refractor. The companion, now known as Sirius B, is about the size of Earth, but it has the same mass as the sun, giving it a density 10,000 times that of lead. Even though Sirius B is 4,000 kelvins hotter than the sun, it's only 0.002 as bright because there's not much surface area to emit light.

Sirius B was the first white dwarf discovered. Stars that range up to about 10 solar masses leave these slowly cooling embers behind when they die. As the star uses up its nuclear fuel, the energy that supported it vanishes and gravity takes over. The star's core collapses into a much smaller sphere, so small that the electrons in each atom are pushed as close together as they can be. A teaspoon of this so-called degenerate matter would weigh a ton if transported to Earth.

Despite their name, not all white dwarfs are white. They change color as they cool, fading to yellow, to orange, to red, and finally to black. These stellar corpses take billions of years to cool completely, longer than the current age of the universe. Every white dwarf that ever existed still glows, if only dimly.

Brown Dwarfs and Planets

If you like cool and dim, let's head on over to Gliese 229, a red dwarf 18.5 light-years from Earth (disco was still the rage when the light we see today left that star). In 1994, astronomers spotted a faint companion orbiting the star at about the distance Pluto orbits the sun. The companion, Gliese 229B, turned out to be the first confirmed sighting of a brown dwarf.

Brown dwarfs are the little stars that couldn't. Brown dwarfs form in the same manner stars do, from collapsing gas clouds. But bodies with less than 8 percent of the sun's mass don't have enough gravity to squeeze their cores to high enough temperatures and pressures to sustain nuclear fusion, the process that makes stars shine. Gliese 229B is 20 to 50 times more massive than Jupiter, with a similar hydrogen/methane atmosphere, but it's about the same diameter as Jupiter because its stronger gravity compresses it. Much as the leftover energy from gravitational contraction in the solar system's gas giants causes them to radiate energy, Gliese 229B's great mass gives it a temperature of about 1,000 kelvins, giving the world a dim reddish glow (despite their name, brown dwarfs would probably look much more red than brown).

Fifty light-years away lies a star that, in 1995, generated some of the greatest excitement in years. The star 51 Pegasi is nothing special in itself, it's a run-of-the-mill yellow sun-like star. But Swiss astronomers Michel Mayor and Didier Queloz noticed that it wobbles slightly, suggesting an orbiting companion.

Mayor, Queloz, and many other astronomers believe they've found the first planet orbiting a sun-like star outside our solar system. A strange planet, 51 Pegasi B is about half the mass of Jupiter but in an orbit that's eight times closer to its star than Mercury is to the sun. At that distance, the planet races around the star so fast that its year lasts a mere 4.23 Earth days. And the star's heat cooks the planet to a temperature of 1,800° F (1,000° C). Because astronomers have only observed the planet's gravitational influence on its host star, they don't know how large it is or what it is made of, although they think it is similar to the gas giants of our solar system.

Astronomers had already identified a system of three planets orbiting a pulsar (the collapsed remnant of an exploded star) and they soon discovered planets around several other solar-type stars. Four of the new planets appear to be virtual carbon copies of the 51 Pegasi planet, while the other planets orbit farther from their host stars. Most of the planets found so far are probably gas giants like Jupiter, and many reside at distances from their suns that make life unlikely. But these systems may have other as yet undiscovered planets at distances that could support life.

According to current models of planet formation, giant planets can't form close to their host stars. So some scientists speculate that the 51 Pegasi planet and its four cousins formed farther away from their suns then migrated inward.

A Stellar Sextet

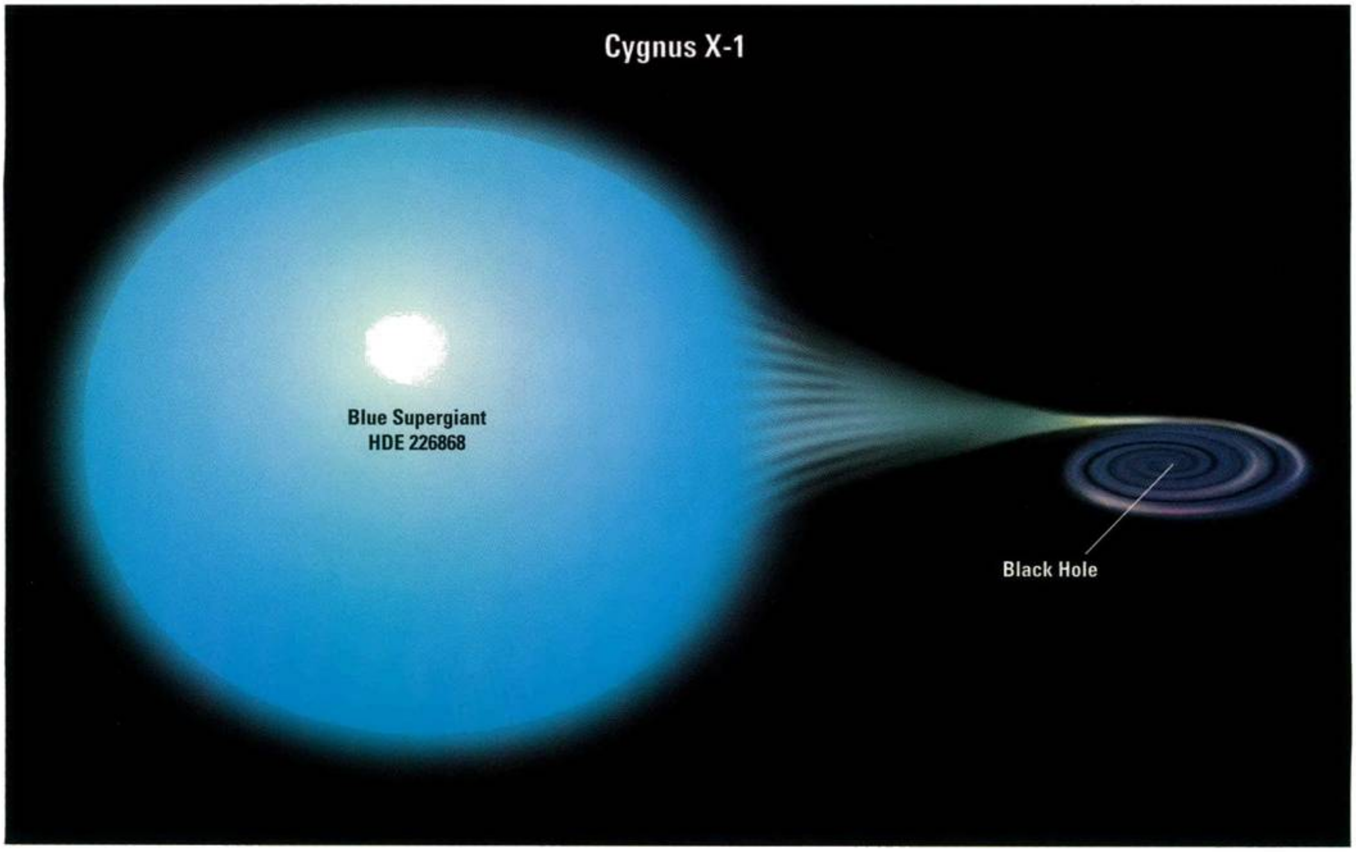
There are stars with orbiting planets and stars orbiting other stars. How about a system of six stars? Castor, 45 light-years away in Gemini, looks like a binary system in a backyard telescope. English astronomer Sir William Herschel demonstrated, in 1803, that the two stars, Castor A and B, are gravitationally bound, the first system in which two stars were shown to be revolving around each other. In this case, they orbit around a common center of mass every 380 years, with an average separation of 90 AU. In 1965 they came within 55 AU of each other, which is as close as they get.

Not everything in the heavens is as it first appears. From observations of the stars' spectra, it turns out that the brighter of the pair, Castor A, is actually two stars 4 million miles apart (0.04 AU), revolving around each other every 9.2 days. Both are hot, white stars, about twice the diameter of the sun and 12 times brighter. Between them they have the mass of 3.2 suns. Castor B is also a pair of hot, white stars, less than three million miles apart with a circular 2.9-day orbit. Each star is about 1.5 times the sun's diameter and six times brighter. Together they contain 2.3 solar masses.

But it doesn't stop there. About 100 billion miles from A and B, or more than 1,000 AU away, is Castor C, with an orbit so large astronomers haven't nailed down the time period yet. They think Castor C orbits Castor A and B once every 10,000 or more years. And, surprise — Castor C is also a binary star, a pair of red dwarfs much smaller and less luminous than the sun. The dwarfs are 1.67 million miles apart, a mere 0.02 AU, and orbit each other in 19.5 hours.

A Black Hole and a Nova

Many binaries consist of two stars similar to each other in mass and temperature. But that's not always the case. Take the inauspiciously named HDE 226868 in the constellation Cygnus. This star is a blue supergiant, one of the



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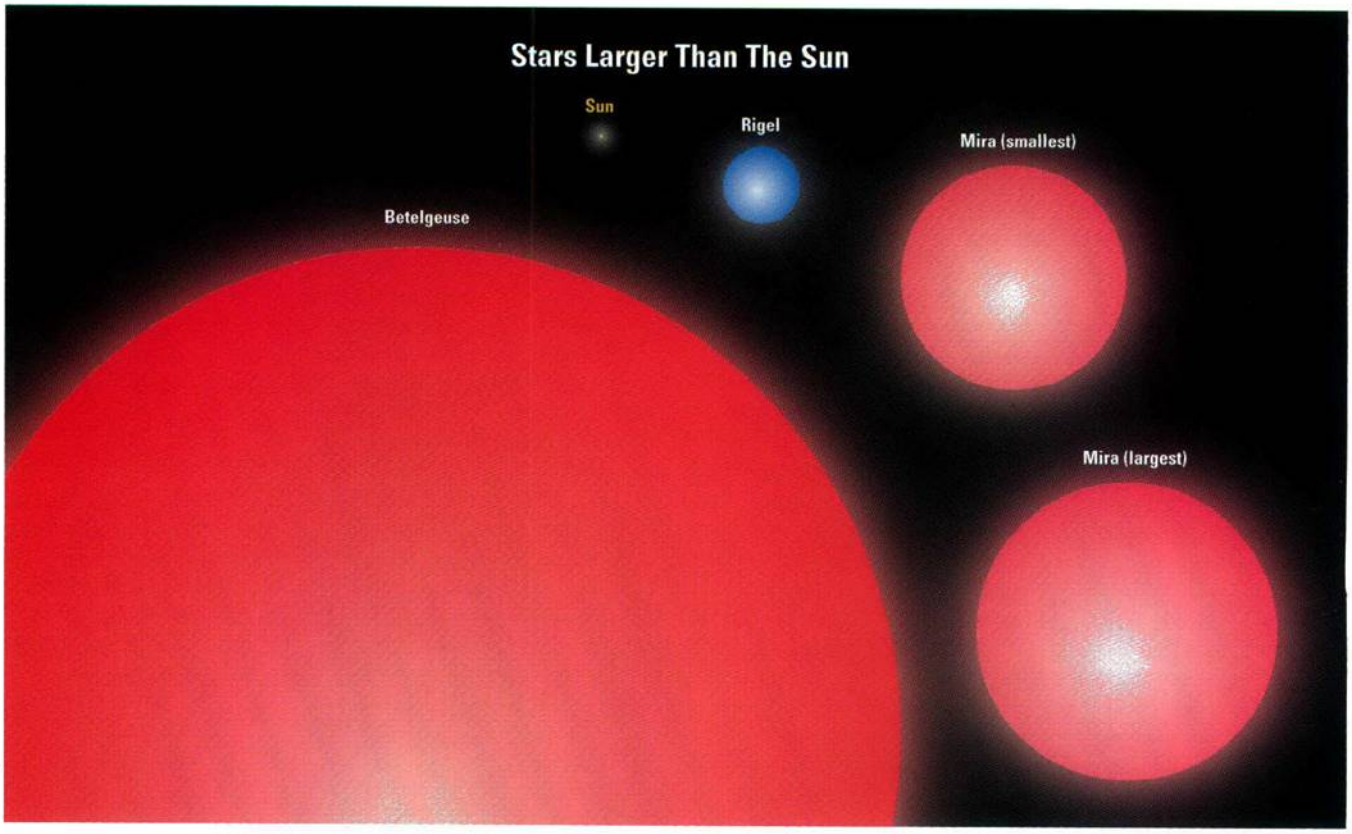

Astronomy: Elisabeth Rowan

behemoths of the galaxy. Blue supergiants are several dozen times more massive than the sun, 20,000 or more degrees hotter, several thousand times larger, and millions of times more energetic. You wouldn't want to venture too close to a blue supergiant.

In the early 1970s, the Uhuru x-ray satellite discovered a powerful x-ray source associated with HDE 226868, and astronomers named the source Cygnus X-1. They also found that the star had an orbital companion they couldn't see and that the two objects revolved around each other every 5.6 days. To make a massive supergiant revolve that fast, the invisible object had to contain more than three solar masses. That object was at least three times more massive than the sun, yet too small and dark to be seen. Astronomers have probably found a black hole — an object whose gravitational grip is so powerful that not even light, the fastest thing in the universe, moves fast enough to escape.

The universe obeys the rule of the bigger they are, the harder they fall. Stars that start out with up to 10 or so solar masses have cores that collapse to white dwarfs, where the degenerate matter is packed so tight that only the pressure of the electrons supports the weight of the matter. At more than 10 solar masses, the collapsing stellar core is so massive that even the electrons can't push it back, so gravity scrunches the core into an incredibly dense, city-sized neutron star, where only the repelling force between neutrons in the atoms supports the matter from further collapse. But if the original star is even more massive (scientists aren't sure just how massive) the gravitational force of the core collapse overpowers even the neutrons, and the whole thing squeezes into a black hole.

X rays are the scream of dying matter being pulled into Cygnus X-1's black hole. The black hole's powerful gravity rips gas from the blue supergiant. The gas forms a whirlpool-like disk around the black hole, spiraling ever closer to the black hole until it plunges in and disappears from the universe forever. As the gas speeds down this enormously steep gravity well, it heats up to more than a million degrees, so hot that it radiates x rays.

Something similar happened to Nova Cygni 1992. On February 18, 1992, a bright new light suddenly appeared in the constellation Cygnus. Astronomers determined that the nova (Latin for "new") flared in a binary system some 9,000 light-years away. This system consists of a red dwarf orbiting a more massive white dwarf. Gas from the red dwarf's stellar wind spilled over into the white dwarf's powerful gravitational field. This gas forms a disk around the degenerate star before spiraling inward. Just as with the black hole, the infalling gas heats up. But instead of disappearing, it lands on the white dwarf's surface. Over several thousand years, this gas collects and heats up. Suddenly, when the gas temperature reaches a critical level, a runaway thermonuclear reaction starts, heating the gas by billions of degrees. The superheated layer explodes with the force of millions of hydrogen bombs, throwing off a shell of gas and a burst of radiation.

Because only the gas on the white dwarf's surface actually explodes, both stars survive, and the eruptions can recur every few thousand to tens of thousands of years. By examining the spectrum of the nova's light, scientists determined that this white dwarf has a high concentration of neon, an element that could only have been made by an extremely massive red giant star. Although it's now the smaller star in the system, the white dwarf must once have been thousands of times larger than the red dwarf.

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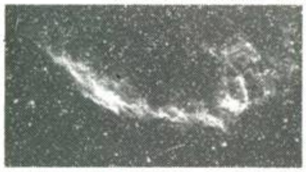

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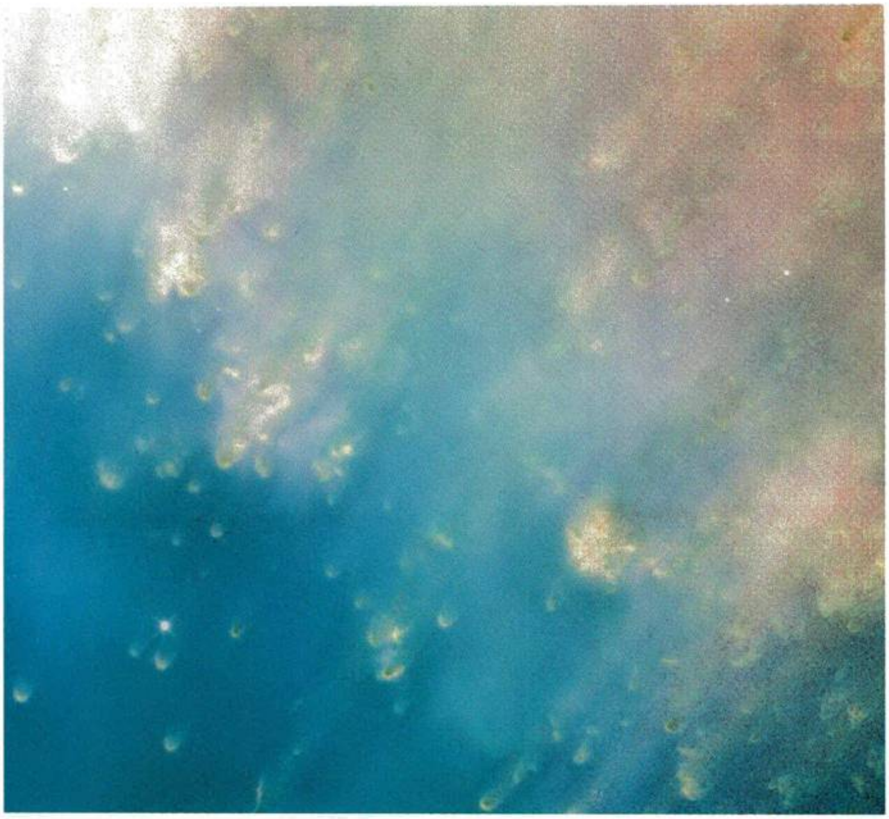
The Giants

Alpha Centauri A, B, and C, 51 Pegasi, Sirius A, the six stars of Castor, and our own sun are various types of main sequence stars, stars whose colors and temperatures are determined by their mass. Main sequence stars are in the main part of their life cycles, living on the energy they create by fusing hydrogen into helium. When stars reach the latter stages of their life cycles, they change substantially.

Take Mira, for instance, located about 150 light-years away in the constellation Cetus. Most of the time, the star is so faint that it can't be seen with the naked eye. But at other times, it's 250 times brighter and a prominent naked-eye object. When astronomers first noticed in the 1600s that this star brightened and faded with a period of about 330 days, they named it Mira, Latin for "wonderful." Mira is a little more massive than our sun, and was



C. Robert O'Dell (Rice University) and NASA

A Hubble image (left) shows colliding stellar winds in the Helix Nebula (below), the closest planetary nebula. The collision fragments the gaseous ring into globules.

Anglo-Australian Telescope Board/Photography by David Malin once an intermediate-sized dwarf like our sun. But eventually it used up all the hydrogen in its core. The core, then rich in helium, contracted. But in doing so it heated up, and the heat pushed the gas in the star's outer envelope outward. Under the growing heat and pressure, the helium started fusing into carbon and oxygen, allowing the outer envelope to contract. Eventually, this helium was used up, and the star swelled again. Now there's a carbon-oxygen core, surrounded by a shell of burning helium, which in turn is encased in a shell of fusing hydrogen. As it goes through its death throes, Mira expands and contracts. The star is now a pulsating red giant.

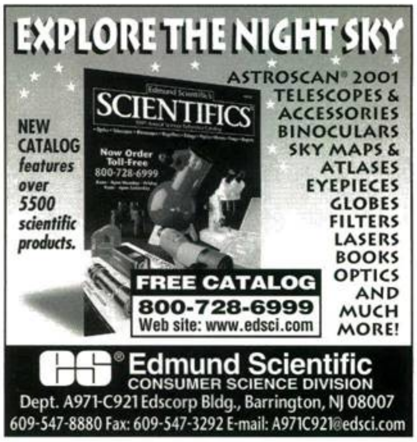
Even though the outer layers are several thousand degrees cooler than the sun's surface, Mira is bright because it's enormous. If it were in the sun's place, the outer envelope would extend near Mars when it's at maximum size. As Mira shrinks to near its minimum size, it would still reach beyond Earth. Mira has a few hundred thousand years left at most. Eventually it will have no fuel left to burn, and its core will collapse to a white dwarf surrounded by an expanding shell of gas. You might say it's like looking in a Mira (sorry for the bad pun) because our own sun is destined to suffer the same fate 5 billion years from now.

One of the largest stars in the galaxy is the red supergiant Betelgeuse, the bright star at the left shoulder of Orion. Betelgeuse is a huge, cool star about 1,000 light-years from Earth. In the sun's place, it would reach nearly to the orbit of Jupiter, but its surface is only 3,400 kelvins. It was once, however, smaller and a lot hotter, probably a blue dwarf. Like Mira, it used up its initial fuel supply and is now burning its reserves. Betelgeuse is about 10 to 20 times more massive than the sun. It's great mass caused it to burn hotter and faster. The life span of a star like Betelgeuse is only 10 or 20 million years, about a thousandth the life expectancy of our sun.

Another notable star in Orion is the blue supergiant Rigel, at the right knee. Rigel is about 1,000 light-years away, but it's one of the brightest stars in our night sky because it shines with a luminosity of 50,000 suns. Yet it's much smaller than Betelgeuse — in the sun's place, it would almost fill the orbit of Mercury. As you might guess, since you know by now that color is a function of temperature, it's much hotter than the sun: 14,000 kelvins at the surface. The sun's core is 15 million kelvins; Rigel's is 100 million.

Stars are forming inside these three pillars of cold hydrogen gas, located in the Eagle Nebula (M16) in Serpens.

Jeff Hester, Paul Scowen (Arizona State University), and NASA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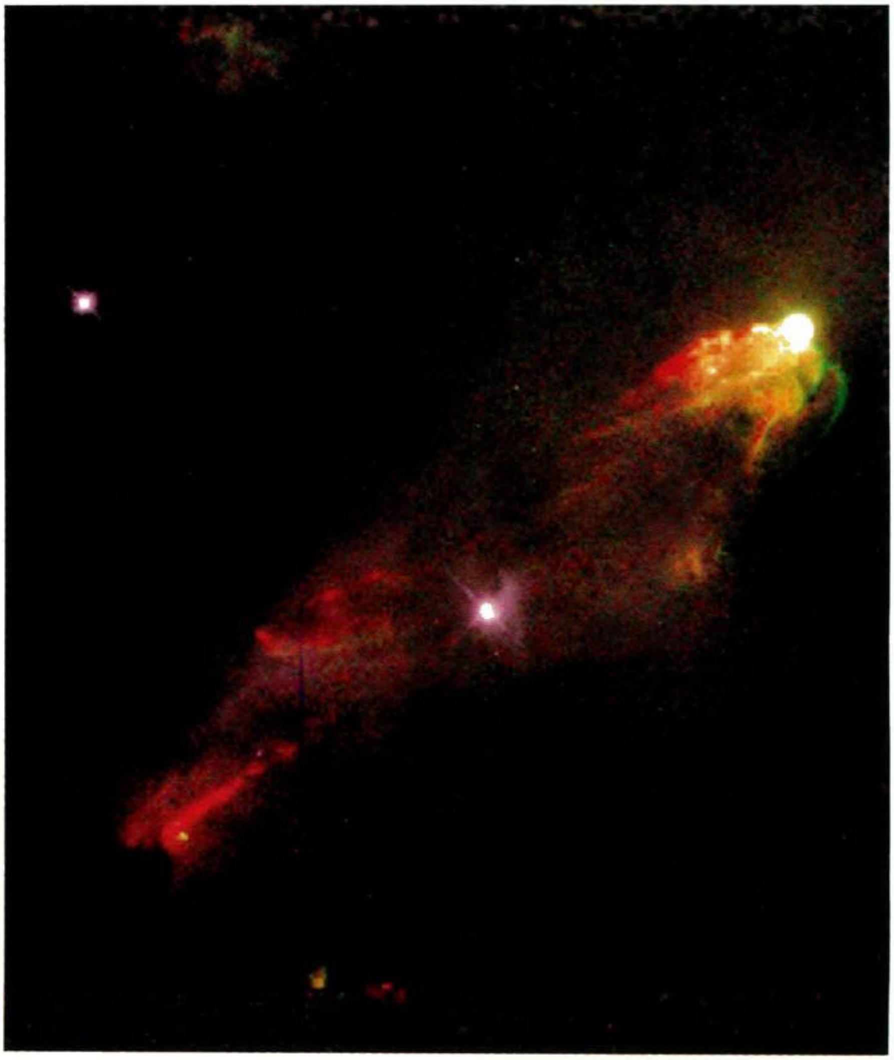
Like Betelgeuse, Rigel is nearing the end of a short but glorious life. In fact, some astronomers think it may once have been a red supergiant like Betelgeuse that shrank and grew hotter again. The most massive stars may cycle between the red and blue supergiant phases before they finally explode in a blaze of cosmic glory, a supernova.

One of the leading supernova candidates is the mighty star Eta Carinae — one of the most massive and luminous stars in the galaxy. Located 8,000 light-years away, it has the mass of about 100 suns and produces 5 million times our sun's energy. In the late 1830s, it suddenly flared up, and for 20 years became the second brightest star in the night sky after Sirius. Images of the star show that it underwent a huge explosion, the most violent one known to not destroy its star. The explosion expelled two or three solar masses worth of material. Recent Hubble Space Telescope images show twin lobes of gas and dust flying away from the star at 1.5 million miles per hour. By projecting the motion of the lobes backward in time, astronomers know their creation coincided with the brightening of Eta Carinae last century. When it eventually goes supernova, sometime in the next few tens of thousands of years, Eta Carinae will produce an enormous burst of light and will probably leave behind a black hole.

Stellar Shrouds

What's left might look like the Crab Nebula in Taurus, an expanding cloud of gas 10 light-years wide and about 7,000 light-years away. Chinese astronomers recorded the supernova that created the nebula in 1054, calling it a "guest star." The nebula itself was not discovered for another 700 years.

This Hubble image shows HH-1, a jet of hot gas shooting away from a newborn star at supersonic speeds. The jet spans several light-years. The star is obscured by dust.



Jeff Hester (Arizona State University), et al., and NASA

The cloud is growing at the rate of 2.25 million miles per hour, and it glows brightly as the neutron star — the city-sized remnant of the exploded star — continues to energize the surrounding material. The neutron star rotates 30 times per second. Hot spots at the star's magnetic poles sweep beams of energy across space the way a lighthouse sweeps beams of light across a bay. If a neutron star's beams are oriented so they sweep by Earth, astronomers call the neutron star a pulsar.

Closer to home is the Helix Nebula in Aquarius; at 450 light-years it is the closest planetary nebula to Earth. The name "planetary nebula" is actually a misnomer. They have nothing to do with planets — they just happened to look like planets to the 18th-century astronomers who first observed them. Planetary nebulae are actually the death shrouds of stars that started their lives with up to about 10 times the mass of the sun. When stars expand to become red giants, their gravity can't hold onto their distended outer envelopes, which float off into space as dense stellar winds. When a star runs out of energy, its hot core starts shrinking en route to becoming a white dwarf. The dying star radiates tremendous amounts of ultraviolet light, which illuminate the layers of gas previously shed by the star in its red giant phase. For a few thousand years, these layers glow brightly as a planetary nebula.

Hubble pictures of the Helix Nebula show little puffs of dust and gas near the inner edge of the nebula. Those little puffs are actually 100 AU in diameter, with tails up to 1,000 AU long. The white dwarf in the center of the nebula gives off a hot, fast wind of particles that slams into the old, slower-moving wind that was ejected 25,000 years earlier when the star was still a red giant. This collision fragments the nebula into these knots of gas and dust. The white dwarf's fast stellar wind will eventually clear away the nebula.

The Helix Nebula is one of the few planetary nebulae that appear round. Many planetary nebulae have peanut or hourglass shapes. All stars blow off gas through their stellar winds, and this process intensifies when they expand into red giants. Early on in their giant phase, many stars blow a slow wind that, for an unknown reason, perhaps due to rapid rotation or the presence of a companion star, is strongest at the equator. Because stars blow most of the their gas from the equator, this creates a donut-shaped circle around the star. Later, a star puts out a faster wind, which blows a spherical bubble of gas around the star. The fast wind eventually catches up to the slower wind released earlier. Because the slow wind is concentrated in a disk, it constricts the bubble in that direction, so the resulting planetary nebula assumes a double-bubble shape.

Stellar Nurseries

Planetary nebulae are associated with stellar death, but many nebulae are places where stars are born. Stars, if you recall, form from collapsing gas clouds, and the material given off in the destruction of older stars provides raw material for new suns and, perhaps, new planetary systems. Nuclear fusion not only makes stars shine, it also produces elements heavier than hydrogen and helium, including the carbon, oxygen, calcium, and iron necessary for building both our planet and our bodies. Carl Sagan liked to point out that we are all starstuff, literally created from the ashes of extinct stars.

The Eagle Nebula in Serpens, 8,000 light-years away, is one star factory astronomers can see in action. Protruding from the main cloud are three gigantic pillars of cold gas up to two light-years long, where gas is condensing into stars. Hubble photos show that as the young stars start burning, they put out a stream of ultraviolet radiation that blows away the nebula's gas, revealing pockets of gas that haven't quite formed stars yet. These evaporating gaseous globules may never become stars because the dust they need to feed on is being blown away.

One of the closest star factories is the Orion Nebula, a fuzzy, glowing patch in Orion's sword, 1,500 light-years away. Among the newborn stars may be planetary systems in the making. Recall that the solar system formed from a collapsing cloud of gas and dust that later formed a disk around the young sun. Astronomers surveyed 110 stars in the Orion Nebula, and found gas and dust around 56 of them, indicating that planetary systems could be fairly common.

In the 1980s astronomers realized that many of these young stars are accompanied by incredibly narrow supersonic jets of hot gas, some of

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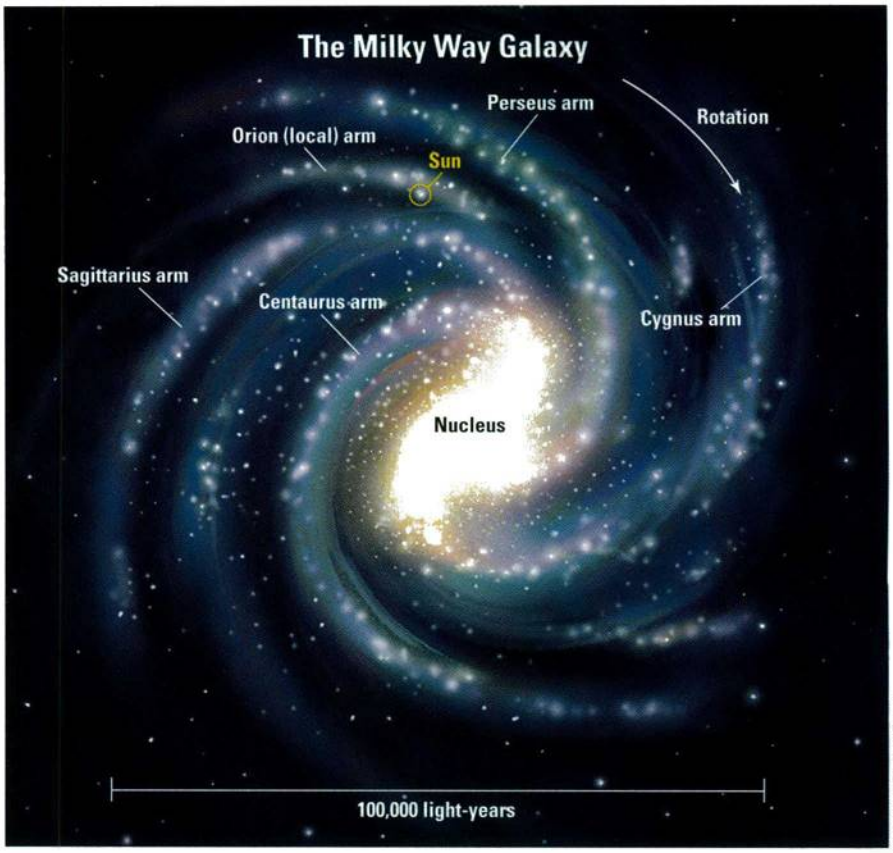


Astronomy: Elisabeth Rowan

which stretch across a dozen or more light-years of space. These jets shoot away from the central star's rotational axis. When a jet rams into the surrounding interstellar gas, the sudden deceleration heats the gas and forms a bow shock similar to the ones produced by speedboats moving across water. Astronomers don't know exactly how these jets form, but they have good reason to think it has something to do with magnetic fields in the disk.

The Milky Way

At 1,500 light-years, the Orion Nebula may seem to be a long way away. And on a human scale, it is. The light we're seeing today left there when the Goths were sacking Rome. (Our old Chevy would never make it. Doing 60 all the way, it would have had to set out almost 17 billion years ago, before the universe was even born.) But in a galactic sense, the nebula is in our neighborhood. The Milky Way Galaxy, a spiral-shaped whirlpool of stars, is 100,000 light-years wide, and contains an estimated 200 billion stars.

About 150 globular clusters surround the Milky Way in a spherical halo. These are groups of stars, usually several hundred thousand, packed into a region about 100 light-years across. At a distance of 24,000 light-years, M13's nearly one million stars make it one of the most impressive telescopic sights. Stars in M13's core are spaced only about one light-year apart. Every 300 million years or so, a globular cluster passes through the plane of the galaxy. These encounters sweep the space between the cluster's stars free of gas and dust, making it impossible for the cluster to form new stars. Globular cluster stars are thus among the oldest in the universe.

Another kind of star cluster is the open cluster, a much smaller concentration of a few dozen to a few thousand stars. The most famous open cluster is the Pleiades, the Seven Sisters of Greek myth, which are about 360 light-years away. Seven of the cluster's 400 to 500 stars can be seen with the naked eye. In contrast to globular clusters, open clusters generally contain young stars that formed together inside the same gas cloud. And whereas globular cluster stars remain gravitationally bound for billions of years, open clusters eventually break apart.

The galactic disk is 3,000 light-years thick in our neighborhood, but it bulges to 16,000 light-years in the center. We're a little more than halfway between the edge of the disk and the galactic center, which lies 27,000 light-years away in the direction of Sagittarius. Ancient stars are packed close together near the core. If you could stand on a planet near the very center of the galaxy, you would look into a sky ablaze with the light of millions of stars (on Earth, the average person can see 6,000 stars with the naked eye). But you wouldn't want to get too close to the center, and not just because of the commute. Astronomers believe the center of the galaxy holds a massive black hole, by far and away the most massive one in the Milky Way.

Astronomers have found that gas at the center of the galaxy swirls around the core at speeds of several hundred miles per second, indicating the presence of a powerful gravitational field. They have also found an energy source in the core that radiates five times as much energy in radio wavelengths as the sun gives off in light. This radio source, Sagittarius A*, is probably a black hole with the mass of about 2.5 million suns. As hot gas plummets into the black hole, it gives off radio waves, just as Cygnus X-1 radiates x rays. The majority of large galaxies appear to have black holes at their centers — including the neighboring Andromeda Galaxy, also known as M31.

In fact, the Hubble Space Telescope has confirmed the presence of a supermassive black hole in the center of the giant elliptical galaxy M87, 50 million light-years away. M87 is also a radio galaxy, a strong emitter of radio waves. A 40,000-light-year-long jet of charged

The Large Magellanic Cloud is an irregular galaxy containing 20 billion stars. It orbits the Milky Way Galaxy.

Luke Dodd

subatomic particles shoots out from the galaxy's center at near light-speed. Hubble has photographed a disk of rapidly swirling hot gas around M87's core. To be spinning at 1.2 million miles per hour, it must be subject to a gravitational pull equivalent to 3 billion suns. But the gas seems to be swirling around a relatively dark area no bigger than our solar system. The most plausible explanation is a gigantic black hole.

Galaxies

The old song says "Be true to your school," and you should feel that way about your galaxy, too. Don't let anyone tell you the Milky Way is "just an average galaxy." In fact, it's much larger than most galaxies and is the second largest in the Local Group — a conglomeration of at least 35 galaxies gravitationally bound to one another. The Andromeda Galaxy, 2.4 million light-years away and just about the farthest object you can see with the naked eye, is slightly larger than the Milky Way, containing some 300 billion stars.

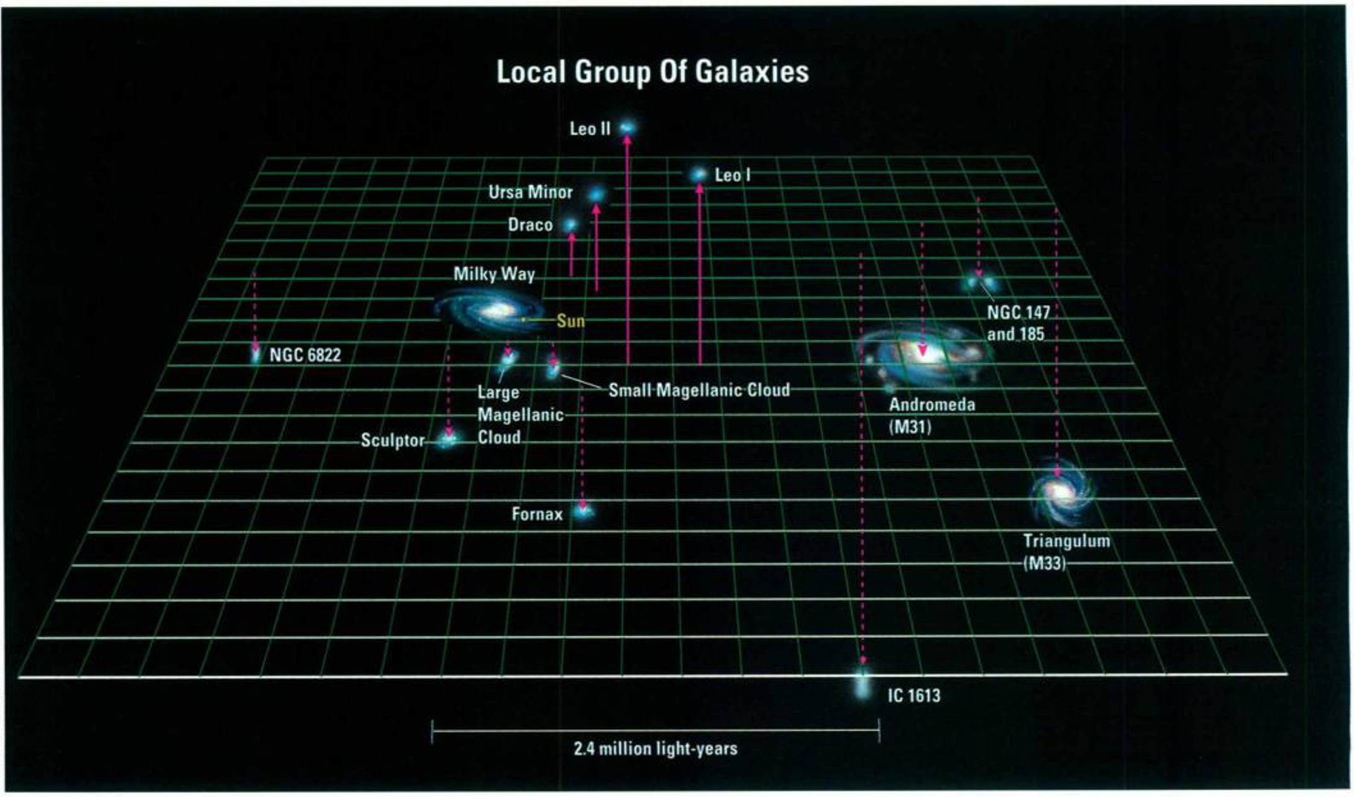
The Milky Way and Andromeda are spiral galaxies, so named for their pinwheel shape. About a third of the 100 billion or so galaxies in the observable universe are spirals, which typically have a bulging middle, a flattened disk, and a spherical halo of globular clusters. The arms of spiral galaxies appear bright not because the space between them is empty, but because compression waves concentrate gas in these regions, forming massive, luminous stars. The spiral arms can wrap around a galaxy's core tightly or loosely; the Milky Way falls in the middle of the range. Some spirals, including the Milky Way, have a bar running straight through the center, with spiral arms trailing off from the ends.

Elliptical galaxies — which vary in shape from balls to fat cigars — comprise the other major galaxy type. Unlike spirals, in which the stars all orbit the galactic center, the stars within an elliptical galaxy wander in a multitude of orbits. The largest elliptical galaxies tend to be much larger and more massive than spiral galaxies, but they have less gas and dust available for new star formation. Because it takes second-generation stars, which contain raw material produced by a first generation, to build planets and complex life forms, elliptical galaxies don't seem likely to harbor advanced life.

Some galaxies are irregular, following no fixed pattern. The largest nearby example — which also happens to be the biggest galaxy orbiting the Milky Way — is the Large Magellanic Cloud, a congregation of some 20 billion stars about 160,000 light-years away and easily visible to the naked eye from the Southern Hemisphere. Most of the other dozen or so Milky Way satellite galaxies are dwarfs, with stars counted in the millions rather than billions. One of these dwarf galaxies is so close to the Milky Way that our galaxy's powerful gravity is tearing it apart. Within a few billion years, the Milky Way will pull the Large Magellanic Cloud apart. In fact, the Milky Way has probably been gobbling galaxies for eons. By stealing dust and gas from smaller galaxies, it can fuel the growth of new stars.

The Large Magellanic Cloud, named after the 16th-century Portuguese explorer, is home to Supernova 1987A — so named because it was the first supernova observed in 1987. Supernova 1987A was the brightest supernova seen in 383 years. Recent Hubble photographs show three rings of material surrounding the explosion's debris, rings that represent material shed by the progenitor star before it exploded. Astronomers expect the innermost ring to brighten around the year 2007, when the expanding shell from the explosion smashes into it.

While the Local Group has about 30 galaxies spread across three million light-years of space, the Virgo Cluster



Local Group Of Galaxies

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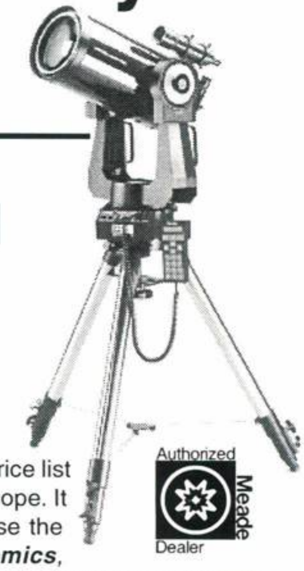

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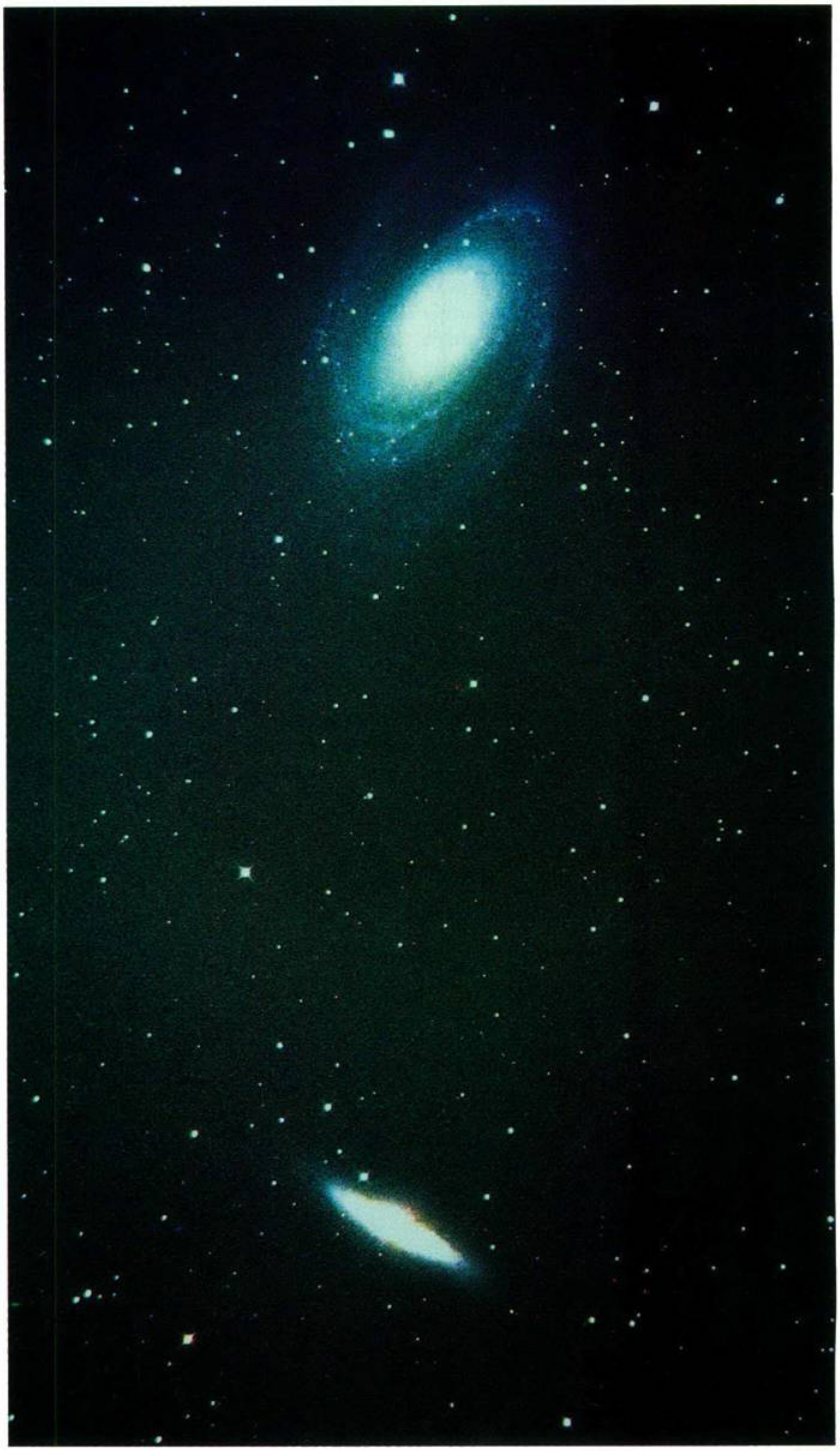

Ron Royer

Galaxies M81 (top) and M82 (bottom) recently passed close to each other, which triggered a starburst in M82.

holds 2,500 galaxies over 10 million light-years. Because the cluster lies 65 million light-years away, the light we see left this group of galaxies back when the dinosaurs were dying. The Local Group, the Virgo Cluster, and 100 other clusters make up the local supercluster, which is about 100 million light-years across and 10 million light-years thick. Between superclusters stretch vast, nearly empty voids.

With all the galaxies that have been cataloged, it's surprising to realize that astronomers may have missed the majority of galaxies. Astronomers have recently been finding hard-to-spot conglomerations called low surface brightness galaxies. The surface brightness of a galaxy depends on how much light it emits per area of space. A hefty galaxy like ours, or a tightly packed dwarf galaxy, is relatively dense in stars, so surface brightness is high. But in many galaxies the stars are spread so thin that the galaxy becomes nearly invisible. Planets in these galaxies would have virtually starless night skies.

In 1986, for instance, David Malin of the Anglo-Australian Observatory took a picture of a fuzzy blob 700 million light-years away. This blob turned out to be a humongous spiral galaxy more than 700,000 light-years across, seven times the diameter of the Milky Way, with 10 times our galaxy's gas content and 20 times its mass. But the gas in the galaxy, now called Malin 1, is so spread out that it has a difficult time forming stars. Even though Malin 1 contains more stars than the Milky Way, they are spaced farther apart, so there's a lot more darkness than light in Malin 1's disk.

While little star formation goes on inside low surface brightness galaxies, other galaxies burst with star formation — an event often triggered by galactic collisions. About 500 million light-years away is the Cartwheel Galaxy, which has a bright yellow nucleus surrounded by a ring of young, blue stars 80,000 light-years from the center. Astronomers think a galaxy plowed through the center of the Cartwheel, and the resulting shock wave spread out like ripples in a pond, compressing gas into a ring of newborn stars.

Two galaxies, known as the Antennae (NGC 4038 and NGC 4039) because they look like the headgear of a cartoon bug, are in the process of colliding. Several hundred million years ago, the two spiral galaxies passed closely and began to tug on each other. They've pulled ribbons of gas, dust, and stars out of each other's disks, creating a system more than 500,000 light-years across. Eventually the two Antennae galaxies will become one. When galaxies collide their individual stars generally do not, because they are spaced so far apart. However, these galactic close encounters jostle gas clouds in both galaxies, often triggering rounds of intense star formation.

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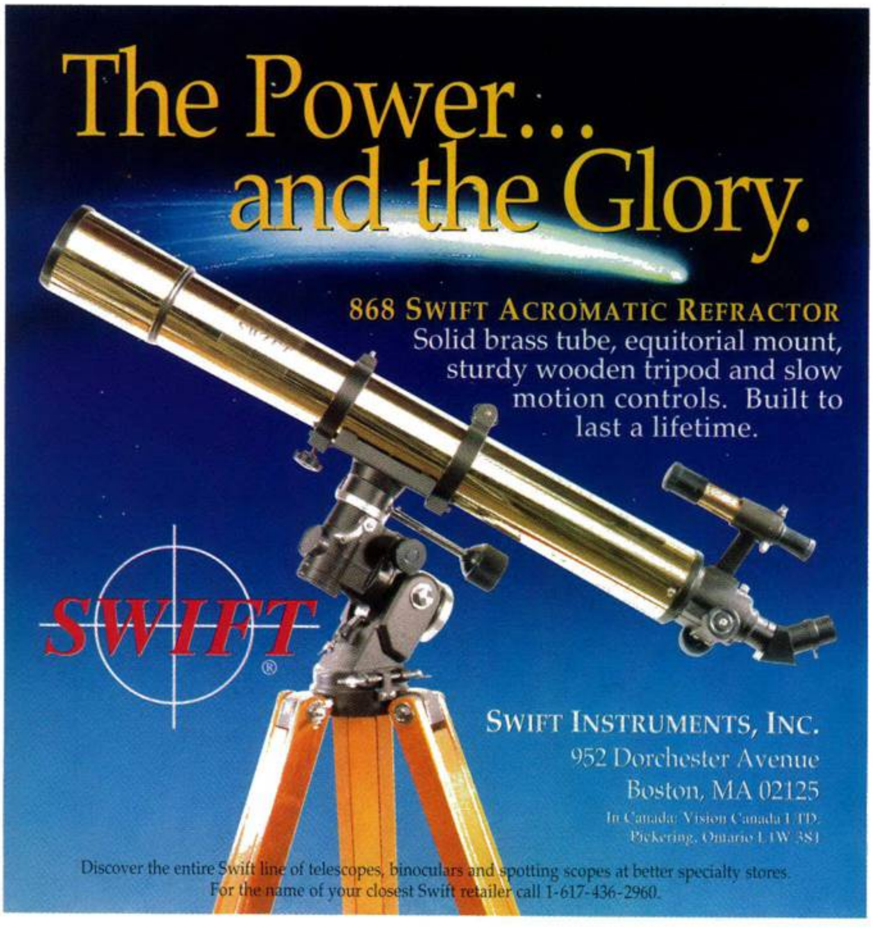

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Near misses can have an effect, too. About 10 million light-years from us, in the direction of Ursa Major, lies M81, a spiral galaxy about as large as the Milky Way. Millions of years ago M81 went sailing past M82, an irregular galaxy with only a tenth of M81's mass. M81's huge gravitational force caused M82's gas clouds to start slamming into one another, igniting a burst of star formation. Each year the tiny galaxy's central region alone turns 10 suns worth of gas into stars, a rate twice that over the entire disk of the much larger Milky Way. The furious rate of star creation has earned M82 the designation of a "starburst galaxy."

The Violent Universe

Such galactic train wrecks answer a 30-year-old mystery, the nature of quasi-stellar objects, better known as quasars. Quasars shine with the energy of trillions of suns, yet their energy comes from a region of space no larger than the solar system. Quasars are located at great distances, meaning we see them as they existed in the distant past. In fact, quasar light has traveled so far that space itself has grown considerably in the meantime, stretching their wavelengths and making their light appear redder. Most quasars date back to a couple of billion years after the universe was born.

Back then, everything was closer together, so the chances of galaxies smashing into one another were much higher than they are today. Many astronomers believe that galactic mergers fed material into supermassive black holes. The monster black holes would gobble up entire stars, which would give off intense bursts of radiation as they spiraled toward their doom. Hubble images of some quasars support this theory. But the galaxies around other quasars look relatively peaceful and undisturbed, as if no collisions are taking place. Perhaps there's more than one mechanism at work.

Other unexplained energy detections are short, powerful bursts of gamma rays, which reach Earth, on average, once a day. Gamma rays are the most energetic form of electromagnetic radiation. Scientists have long wondered what could power such energetic outbursts, and for a while they blamed events taking place on the surfaces of neutron stars within our galaxy. But if neutron stars were responsible, the bursts should be concentrated in the galaxy's disk, as the stars are. Instead, the bursts seem to be coming equally from every direction — implying that they originate in faraway galaxies. If true, gamma-ray bursts are far more energetic than astronomers had ever imagined. Scientists are still trying to figure out what causes them.

Looking back in time, astronomers also find irregularly shaped, faint blue galaxies. The blue color suggests these are young galaxies in the first flush of star formation, shortly after the time of the quasars but still in the first few billion years of the universe. Some astronomers believe these odd-shaped objects eventually joined together to form the spiral and elliptical galaxies around today. Others think these blue galaxies faded to become low surface brightness galaxies.

The bright, massive elliptical galaxies M84 (far right) and M86 (center) define the core of the Virgo cluster.

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The faint blue galaxies may say something about the fate of the universe. If there's enough mass in the cosmos, gravity will eventually overcome the expansion caused by the initial explosion that created the universe, and everything will fall back together, possibly leading to another Big Bang. If there's too little mass, the universe will keep on expanding forever. A certain amount of mass in between would halt the expansion but wouldn't trigger a recollapse. Scientists aren't sure which scenario will occur, although the bulk of the evidence points toward an ever expanding universe.

No one knows how much matter the universe contains. Theory suggests there should be a lot more than scientists have found. And the behavior of galaxies suggests the existence of dark matter. Stars in the outer fringes of the Milky Way, for instance, orbit the galactic center three times faster than one would predict from the observed mass of the galaxy. The speed suggests a lot more gravitational force than can be found by adding up all the stars and gas clouds in the galaxy. In fact, the visible portion of the galaxy must account for only 10 percent of its mass. And it's not just the Milky Way — almost all galaxies seem to be surrounded by a halo of dark matter.

What could dark matter be? Some astronomers think it's mostly normal matter that's too dim to be seen: faded white dwarfs, brown dwarfs, planet-mass objects, or black holes. They call these MACHOs, or MAssive Compact Halo Objects. Other scientists think the dark matter might be made up of neutrinos, high-energy particles so elusive that most of them pass right through Earth without a trace. Neutrinos are known to exist in vast quantities, but scientists still aren't sure if they have mass. Or dark matter could take the form of some strange subatomic particle that hasn't yet been found, such as the hypothetical Weakly Interacting Massive Particles (WIMPs for short).

Astronomers might not know what most of the universe is made of, but they have good reason to believe it originated in a stupendous explosion some 10 to 15 billion years ago: the Big Bang. Cosmologists know about the Big Bang for two reasons. First, in 1929, Edwin Hubble (for whom the Space Telescope is named) discovered that galaxies are flying apart in every direction. Run time in reverse and it becomes clear that the whole universe must have come from a single point. Second, we can "hear" the "echo" of the explosion that started the expansion. As the hot burst of energy from the Big Bang has spread out over

The Local Group is dominated by the Andromeda Galaxy (M31), shown here, and the Milky Way Galaxy.

George Greaney

Tony and Daphne Hallas

Is anybody out there? Gas clouds such as the Horsehead Nebula contain the raw ingredients for planets and life.

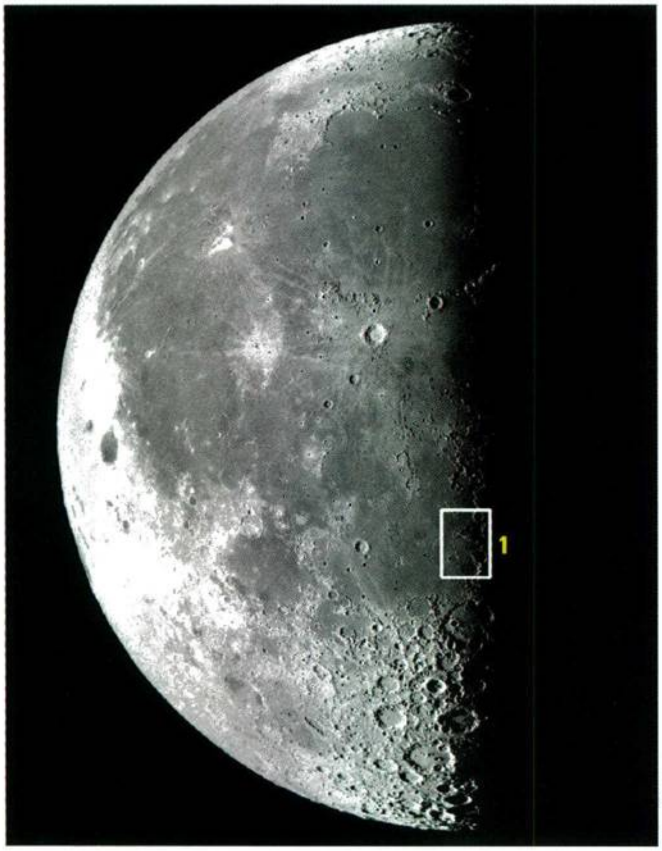
billions of years, it has cooled to just 2.73° C above absolute zero. It forms a microwave background radiation coming equally from everywhere in the universe. In 1992, astronomers found tiny variations in the background, changes of just 30 millionths of a degree. Those variations in the initial conditions were enough to make the universe slightly uneven, causing the clumping that led to galaxies and superclusters.

As to when the Big Bang happened, that's a matter of debate. To figure out how old the universe is, you have to know how fast it's expanding. The faster it's expanding, the less time it took to get to its current size, and the younger it is. You can get an expansion figure by taking a piece of the universe — the Virgo Cluster is a popular choice — and clocking its speed. Current numbers suggest the universe is between 8 and 11 billion years old. Unfortunately, theories about the way stars age say that globular cluster stars are about 15 billion years old. Clearly, stars can't be older than the universe. The problem probably arises because, somewhere in all the estimates of distance, speed, and stellar evolution, some of the values are slightly off. Most astronomers are confident they'll work it out within the next few years.

So what of the speculation that started us on this trek across the cosmos? Could there, somewhere, be a young ET on a distant planet wondering if we're out here? Well, we know our galaxy and others have the ability to produce second-generation stars, which incorporate the heavy elements needed to build planets and living beings. We know that a lot of stars form disks that are believed to be the precursors of planetary systems. We think we've found at least a few stars with planets around them, although so far they're all too big or either too close or too far from their suns to make life probable. We don't know if life arose anywhere other than our own planet, or if it did, how likely it would be to evolve high intelligence. It's not unreasonable to think there might be another technological species out there somewhere. If ET is smart enough, he or she might be able to warp space, or travel through a wormhole in order to get around the cosmic speed limit — the speed of light. But if ET's coming to visit in some alien Chevy, we'll be waiting for a very long time. ◼

Neil Savage is a researcher for the Discovery Channel and a recent graduate of Boston University's graduate program in science journalism. His Honda Civic has enough mileage on it for a dozen trips across the diameters of Io, Europa, Ganymede, and Callisto, with enough left over to cut through Mars.

Discover an *Ancient Moon*



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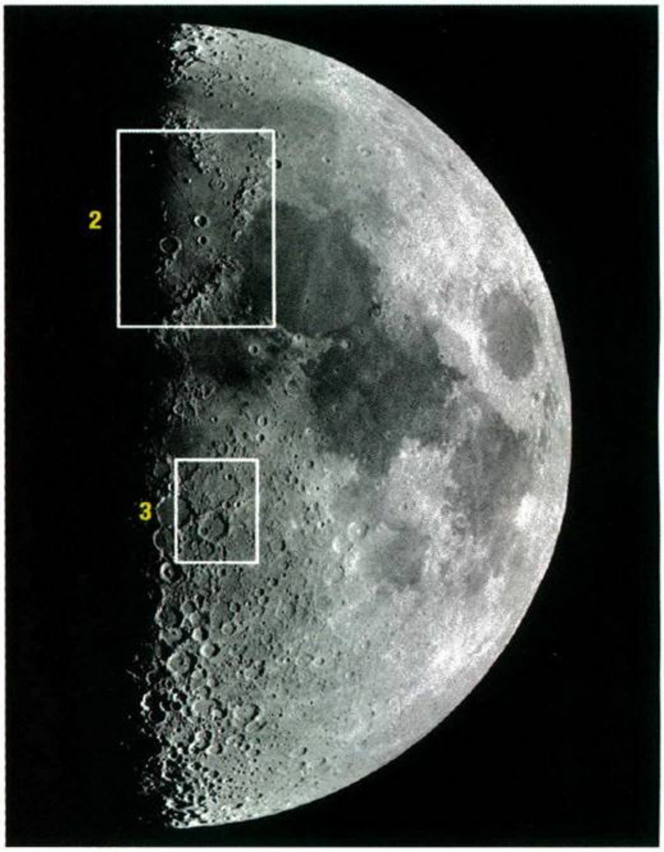
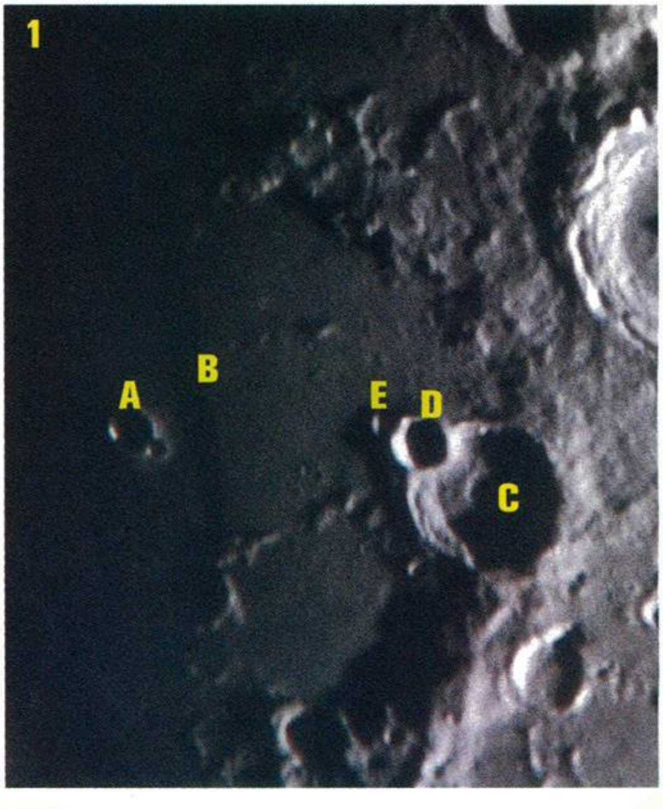


J. Paul Roux

Billions of years of bombardment coupled with ancient geologic activity have covered Earth's companion with craters, flooded impact basins, and other arresting features best seen along the terminator, which divides lunar day and night. Here's some of what you can see in a telescope within a few days of first or last quarter.

Birt and the Straight Wall

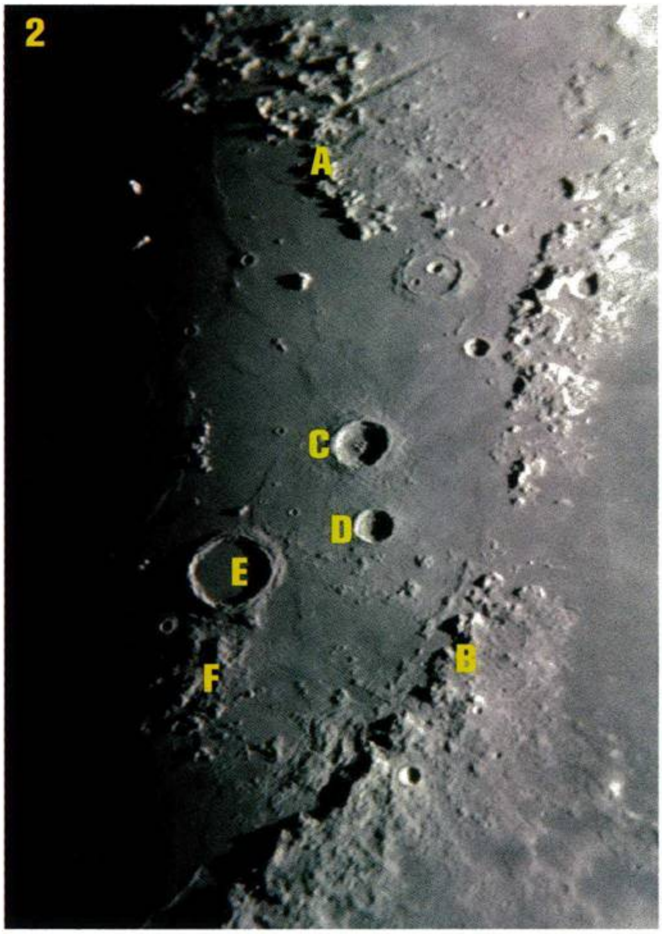
Believe it or not, there's a crater on the moon named **Birt** (A) after the 19th-century lunar cartographer William Birt. Were it not for nearby **Rupes Recta** (B), popularly known as the Straight Wall, 10-mile-wide Birt would be as anonymous as its namesake. The Straight Wall is a fault that's sagged 800 to 1,000 feet over a 70-mile distance. Seven days after new moon it looks like a razor-sharp dark line just east of Birt. Astronomers used to think Rupes Recta was a sheer, west-facing cliff; however, spacecraft pictures show a gentle slope 1½ miles wide tipped at 7°. East of the Wall lies an intriguing triple crater. The northwestern wall of 35-mile-wide **Thebit** (C) appears chipped out by 12-mile-wide **Thebit A** (D), which in turn has its northwestern wall sliced by 6-mile-wide **Thebit L** (E). Or is it that simple? The intertwined walls of Thebits A and L appear to overlap, each unaffected by the other. Could they have formed from simultaneous impacts?



Jean Dragesco

Gateway to the Sea of Rains

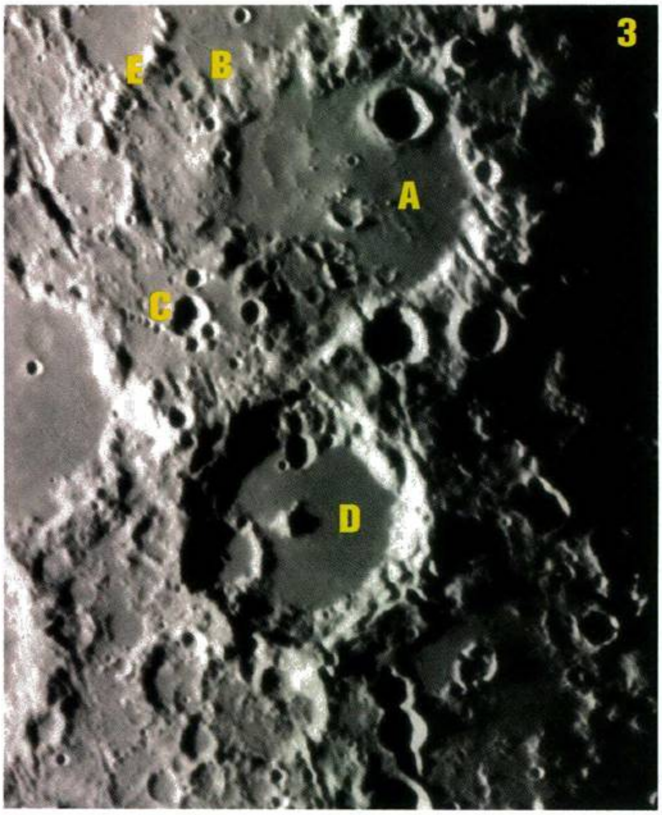
Maria, which comes from the Latin word for seas, are those gray splotches we can see on the moon with the naked eye. Many of them formed approximately 3.8 billion years ago when meteoroids the size of asteroids slammed into the moon and shattered its crust. Lava subsequently bubbled up through the cracks and eventually cooled to create the huge, gray plains. When astronomers first pointed their crude telescopes at the moon, they thought these areas were oceans, and the name stuck. Eight days after new moon, sunlight greets one of the largest and most apparent of the lunar maria: Mare Imbrium, the Sea of Rains. Three large craters and two mountain ranges lie perched along the sea's eastern ramparts. **Montes Alpes** (A) and **Montes Apenninus** (B) respectively define the northeast and southeast shores of Imbrium. These ranges form the rim of the gigantic Imbrium impact basin, which flooded with lava to form the mare we see today. **Aristillus** (C), **Autolycus** (D), and **Archimedes** (E) lie just inside Imbrium's easternmost expanse. Aristillus (34 miles wide) and Autolycus (24 miles wide) make a striking contrast to the flooded floor of Archimedes. Bordering this 52-mile-wide crater to the south is the jumbled **Montes Archimedes** (F) range, which extends for some 90 miles. Under low lighting, Aristillus is also bounded by terraced hillocks, remnants of the impact that formed the crater untold millions of years ago. Its intact central peak and well-defined crater walls suggest an age somewhat younger than the smaller Autolycus. Finally, look about a third of the way from Autolycus to Archimedes to find the area where Luna 2 crashed into the moon on September 13, 1959. This unmanned Soviet probe was the first man-made object to touch another planet.



Jean Dragesco

The Highland Jumble

The lunar highlands harbor some of the moon's most ancient terrain. Craters pile on top of more craters, many of which have been sandblasted to smooth obscurity under a constant drizzle of micrometeoroids. This effect is startlingly apparent on the floor of the 90-mile-diameter crater **Hipparchus** (A). Its subtle hillocks only show up under the low lighting angles afforded around lunar sunrise or sunset. If the night offers steady seeing, glance just outside the northwestern wall of Hipparchus for **Rima Réaumur** (B). This rille, one of more than 2,000 such delicate cracks that formed as the moon cooled and its surface contracted over time, extends for nearly 30 miles. Look southwest of Hipparchus for the 12- by 15-mile-wide crater **Müller** (C) and a string of craters that abut its southwestern wall. This crater chain could be the collapsed lava tube of an ancient volcano or the signature of a machine-gun-like multiple impact. Continue southward to the 85-mile-wide crater **Albategnius** (D). Compare its appearance with the much older Hipparchus to the north. Albategnius still has well-defined walls and a central peak, along with a comparatively unblemished floor. The low sun angle provided by a first or last quarter phase reveals one more regional subtlety. **Parallel faults** (E) that slice through crater and plain alike point directly back toward Mare Imbrium, some hundreds of miles to the northwest. These are stress fractures that formed when areas adjacent to Imbrium cracked under the weight of the mare's vast lava plains.



Jean Dragesco

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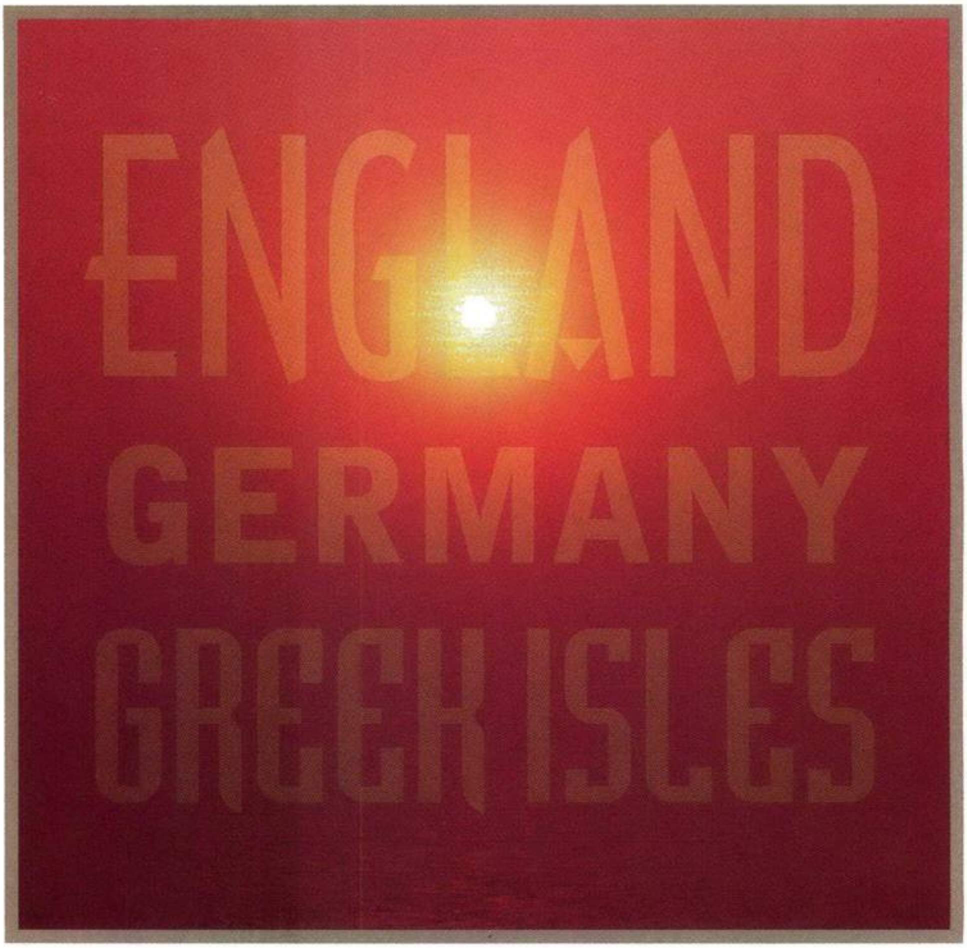

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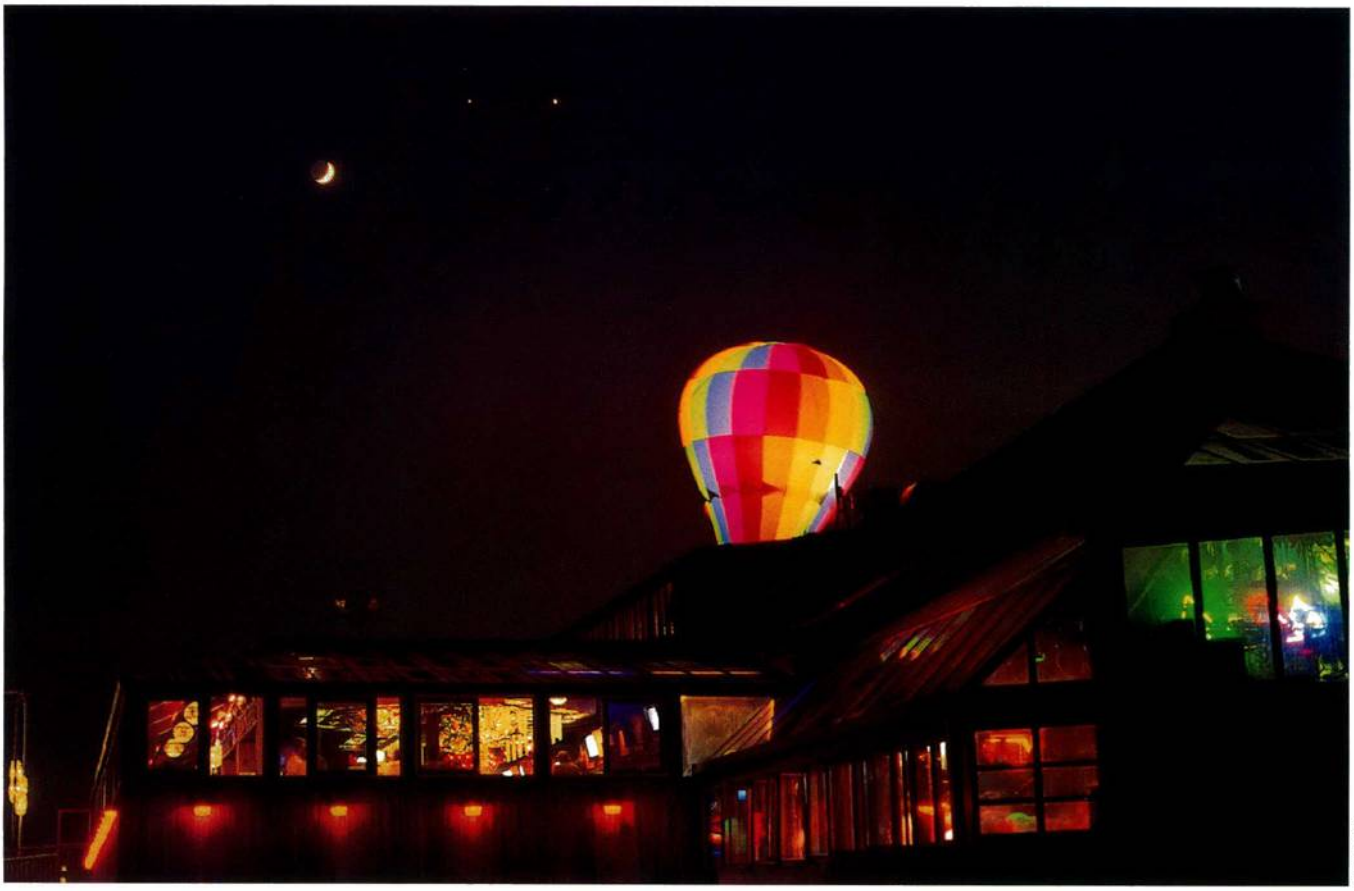
Eye on the Sky

by John Shibley and Richard Talcott


Larry Landolfi

An earthly balloon shared the spotlight with the moon, Mars, Jupiter, and Venus in June 1991 – a preview of some beautiful conjunctions on tap for 1998.

The year 1998 may find it hard to follow the sky spectaculars of the previous two years, but follow up it does with its own masterpieces. Foremost is the first total solar eclipse visible from the Western Hemisphere in more than three years. It happens in February, when the moon's shadow slices across the eastern Pacific, northern South America, and the Caribbean before heading into the Atlantic.

Look to mid-November for the next sky spectacular, when the Leonid meteor shower might storm. In reality, whether we see a storm of hundreds or even thousands of meteors an hour relates to an event that passes largely unnoticed in February. That's the passage of Comet Tempel-Tuttle through the inner solar system on its 33-year-long orbit around the sun. What sets the stage for a meteor storm in November is the attendant debris from Tempel-Tuttle: Earth plows through a dense swarm of dust particles liberated from the comet on previous passages through the solar system. Will our planet dig through the thickest portion? Watch the November skies to find out.

Of course, planets do their share to give the sky some flair during 1998. Tiny Mercury hangs above the western horizon at its best during March, while Venus blazes away as a morning "star" in the east before sunrise. Mars, now one lander richer after last July's Pathfinder bouncedown, lingers as a faint evening object in the west through late winter. From midsummer on, look for it in the morning sky, passing through Gemini, Cancer, Leo, and Virgo as it brightens toward a 1999 opposition. That's when it will lie directly opposite our sun in the night sky for the first time since 1997.

The faint planets of the outer solar system come to opposition during the late spring and summer, when they are visible all night and appear brightest through a telescope. Elusive Pluto arrives on May 28, followed by next-brightest Neptune on July 23 and then Uranus on August 3. Brighter and far more interesting, Jupiter and Saturn choose the autumnal night skies to shine at their best. Look for Jupiter rising at sunset on the evening of September 15; Saturn reaches opposition on October 23.

Don't let these anticipated eclipses, meteor showers, and oppositions lull you into a false sense of predictability. If there's one thing the sky teaches the dedicated skywatcher, it's that the heavens are full of surprises. Just ask Yuji Hyakutake, Alan Hale, or Thomas Bopp. The only way to know when the next bright comet will appear or a normally ho-hum meteor shower might spike is to watch the skies.

JANUARY

S	M	T	W	T	F	S
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4	◐	6	7	8	9	10
11	○	13	14	15	16	17
18	19	◑	21	22	23	24
25	26	27	●	29	30	31

Day	Time (EST)
1	**6 p.m.** **The moon passes 3° north of Jupiter**
4	**Quadrantid meteor shower peaks**
5	**7 a.m.** The moon passes 0.2° south of Saturn
6	**10 a.m.** **Mercury is at greatest western elongation (23°, morning)**
9	**8 a.m.** The moon passes 0.4° north of Aldebaran
16	**6 a.m.** Venus is in inferior conjunction
20	**8 p.m.** **Mars passes 0.2° south of Jupiter (evening)**
26	**7 p.m.** The moon passes 3° south of Venus **8 p.m.** The moon passes 5° north of Mercury
29	**noon** The moon passes 2° north of Jupiter **8 p.m.** The moon passes 1.7° north of Mars

Events in **bold** are ones you won't want to miss.
All times in the calendars are eastern time.
"Morning" or "evening" at the end of a listing denotes that the event appears before sunrise or after sunset, respectively.

Farewell to a Faint Red Planet

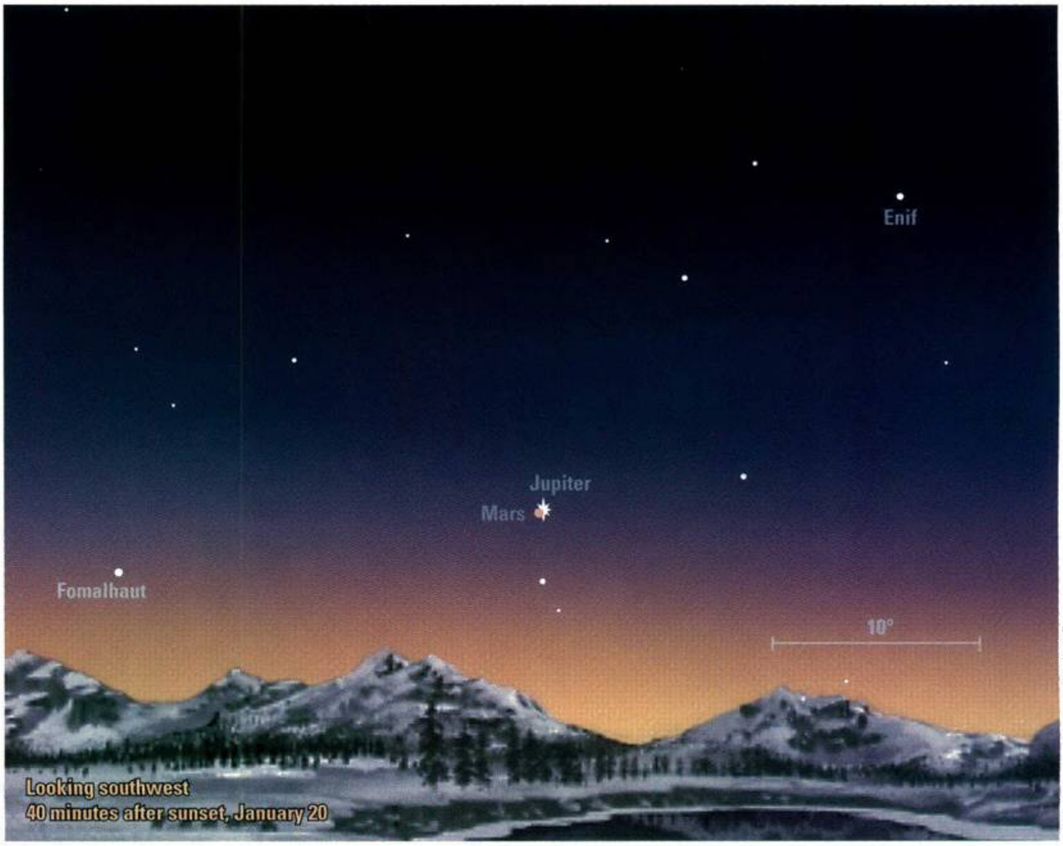
All through last autumn it lingered in the west after sunset, a dusky "star" that seemed to hover above the horizon during evening twilight as other stars kept their appointments with the solar glare. But Mars now has its turn. This spring the Red Planet finally sinks toward a passage behind the sun, called a conjunction, on May 12, something it hasn't done since March 4, 1996. Once it returns to the morning sky in mid-July, it will start a trek toward its next opposition on April 24, 1999, when it will once again shine with prominence all night long. Until then, however, 1998 will be the Year of the Faint Red Planet.

January offers a perfect opportunity for us to draw a bead on diminutive Mars. Jupiter, itself moving closer to a February 23 meeting with the sun, draws close to Mars over the evenings of January 19 through 22. Shortly after sunset on January 20, you can spot the pair a scant 12' — or less than half the width of a full moon — from one another.

Although the two planets appear very close to each other in the sky, in reality 342 million miles of interplanetary space separate the two. As you gaze toward the duo on that Tuesday evening, you are looking past the sun into the solar system beyond: Mars lies 205 million miles from Earth, while giant Jupiter resides at a distance of 547 million miles. On that same day, the sun is relatively close to Earth, a paltry 91 million miles away.

CONJUNCTIONS BETWEEN THE MOON AND PLANETS IN 1998

Date	Planet	Time best seen
Jan. 1	Jupiter	evening
Feb. 1	Saturn	evening
Feb. 23	Venus	morning
Mar. 24	Venus	morning
Mar. 26	Jupiter	morning
Apr. 23	Jupiter	morning
Apr. 23	Venus	morning
June 17	Jupiter	morning
July 17	Saturn	morning
Aug. 20	Venus	morning
Sep. 6/7	Jupiter	all night
Sep. 17	Mars	morning
Nov. 13	Mars	morning
Nov. 27	Jupiter	evening
Dec. 12	Mars	morning



All illustrations by *Astronomy*: Elisabeth Rowan

While we're talking distance, let's also consider the relative sizes of all the players involved. Our sun anchors the solar system with a whopping diameter of 865,000 miles. Just about ten Jupiters, each measuring 89,000 miles across, would string across the solar equator, while it would take 212 Red Planets, each spanning 4,200 miles, to do the same. To continue the comparison, our sun is 109 times Earth's 7,900-mile diameter.

If you bring a telescope to bear on the two planets, you can see them both in the same medium-power field of view. Because they lie near the horizon, you won't see a wealth of detail. Mars shows a disk measuring just 4.2" across that's 98 percent lit. About the only surface detail you might see is the gleaming white south polar cap. On the other hand, Jupiter's 33.5"-diameter globe of hydrogen and helium gas should present at least two dark bands, one on either side of the planet's equator.

There's one final item to mull over as you look upon brilliant Jupiter and ruddy Mars before they set below the horizon. Both these objects are worlds in themselves, like the other planets in the solar system. But only one planet harbors creatures able to ponder a native star system and its denizens.

The Long-Awaited Return of the Leonid Comet

PERIODIC COMETS IN 1998

Name	Perihelion date
Tempel-Tuttle	February 27
Kowal 2	March 1
Tsuchinshan 1	April 19
Klemola	May 1
Arend-Rigaux	July 12
Peters-Hartley	August 11
Howell	September 27
Lovas 1	October 14
Takamizawa	November 7
Giacobini-Zinner	November 21

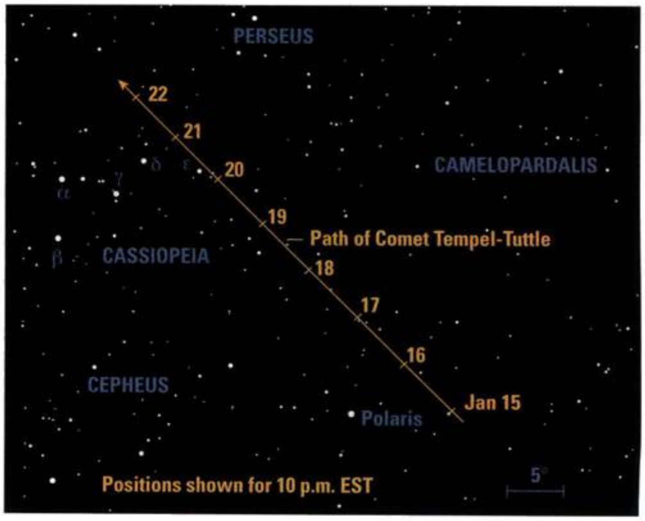
Almost every amateur skygazer with a long memory has been pointing toward this year for a third of a century. Those who were lucky enough to be observing on the morning of November 17, 1966, witnessed one of the great meteor showers in recorded history. As dawn neared, literally hundreds of thousands of meteors rained down on the western United States. The culprit was a comet known as Tempel-Tuttle, which had recently passed through the inner solar system, shedding debris that would some day become future meteors. Well, the comet returns to our neighborhood this month, and it's raising expectations for another great Leonid meteor storm this coming November.

Expect Tempel-Tuttle to look similar to Comet Levy (seen here) during its 1991 return.

Edwin Faughn

The cold nights of January offer the best views of this surprisingly inauspicious comet. At its brightest during mid-January, Tempel-Tuttle should glow around 9th magnitude – certainly no world-beater, but still bright enough to see in binoculars or a small telescope. It follows a path remarkably similar to 1996's Comet Hyakutake, zipping close to Polaris before dipping southward past Cassiopeia. Closest to Earth on the 17th, the comet won't reach perihelion (its closest approach to the sun) until late February, but it is then much farther from Earth and fainter.

Don't expect to see a lot of detail when viewing Tempel-Tuttle. Like most faint comets, it should appear as a roundish fuzzball, perhaps elongated slightly in the direction pointing away from the sun. This elongation is the comet's tail, composed of ionized gas and tiny dust particles. It's those grains of dust that may intercept Earth's trek through space on some future November night, giving us yet another Leonid meteor storm.



Positions shown for 10 p.m. EST

FEBRUARY

S	M	T	W	T	F	S
1	2	◐	4	5	6	7
8	9	10	○	12	13	14
15	16	17	18	◑	20	21
22	23	24	25	●	27	28

Day Time (EST)

1 **4 p.m.**
The moon passes 0.6° south of Saturn

2 **6 a.m.**
Mercury passes 2° south of Neptune (morning)

5 **1 p.m.**
The moon passes 0.2° north of Aldebaran

7 **midnight**
Mercury passes 1.4° south of Uranus (morning)

14 **7 a.m.**
Pallas is in conjunction with the sun

19 **9 p.m.**
Venus is at greatest brilliancy (magnitude -4.6)

22 **3 a.m.**
Mercury is in superior conjunction

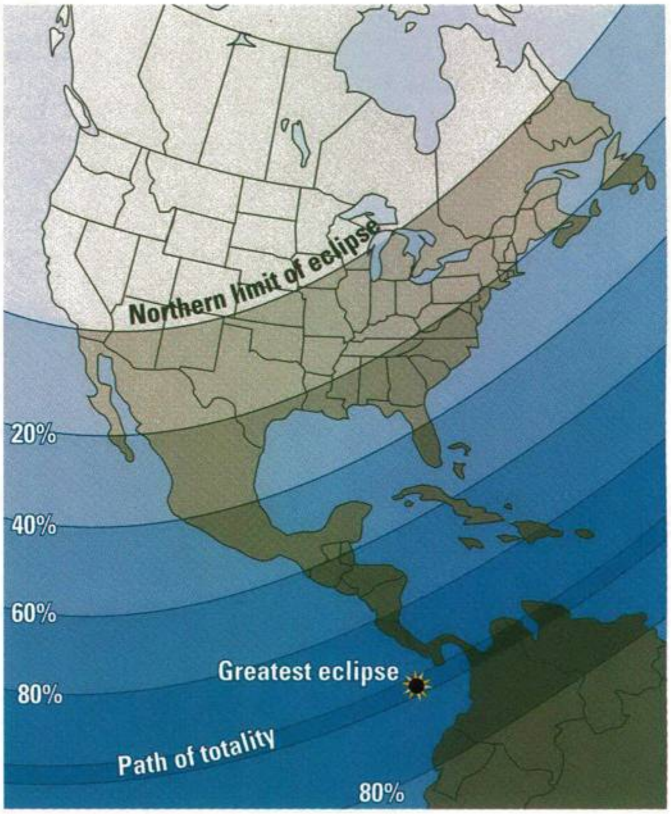
23 **4 a.m.**
Jupiter is in conjunction with the sun
noon
The moon passes 1.6° south of Venus

24 **1 a.m.**
The moon passes 3° north of Neptune
5 p.m.
The moon passes 3° north of Uranus

26 **noon**
Total solar eclipse (visible in northern South America and the Caribbean)

27 **5 p.m.**
The moon passes 0.7° south of Mars

Musings on the Moon's Shadow



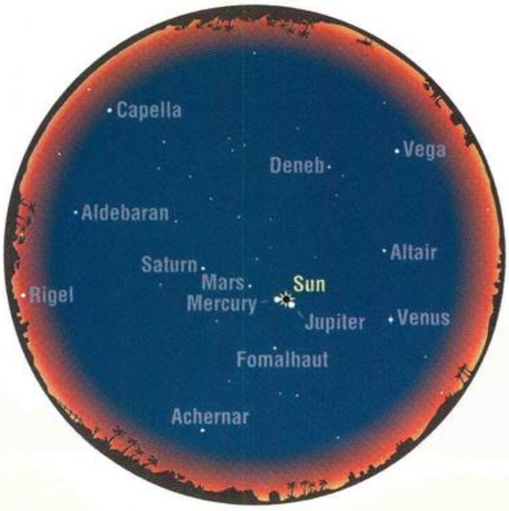
Who can resist the Caribbean in mid-winter? Better yet, who can resist a total solar eclipse over the Caribbean in February? On February 26 the moon's shadow races in at more than 1,300 miles per hour from the Galápagos Islands off the west coast of South America to cut a swath more than 90 miles wide across northern Colombia, through Aruba and Curacao, and into the Leeward Islands.

A solar eclipse like this one lets millions of humans in its path witness an amazing coincidence. Roughly twice a year the moon's 2,160-mile diameter lines up with our sun's 865,000-mile expanse to cast a narrow thread of darkness on Earth. From a distance of 240,000 miles, the moon's apparent size is barely wide enough to cover the sun's face, some 389 times more distant. If the moon were slightly smaller, or orbited Earth just a bit farther away, the sun's brilliant surface would still be exposed to our sight. A bit closer, and the moon would completely obscure delicate prominences seen just above the sun's limb, perhaps even the corona's wispy petals, which stretch out millions of miles and define our star's outer atmosphere.

As it is, our natural satellite admirably fulfills the role of a cosmic sun visor so we on Earth can see all of these features and more. Such a celestial line-up helped usher in our present understanding of the sun. It's only during a solar eclipse that we naturally see the corona, which we now know to be a rarefied plasma that rides solar magnetic fields. Prominences are actually Earth-sized eruptions of gas that jut thousands of miles above the sun's visible surface, the photosphere.

A solar eclipse even clinched a key prediction made by Einstein's general theory of relativity, which holds that gravity bends light. In 1919, two expeditions precisely measured the positions of several stars near the eclipsed sun's limb. The starlight had traveled for hundreds of years at 186,000 miles a second, only to pass through the sun's gravitational field and get deflected from a straight-line path during the final few minutes of its journey. This deflection showed up as a shift in each star's apparent position on photographic plates. Not only was gravity's relativistic nudge revealed for the first time in history, but by the amount Einstein had predicted. So under the false twilight of an eclipsed sun, a new form of 20th-century physics was endorsed, the stuff of black holes, warped space, and expanding universes.

The Sky at Mideclipse



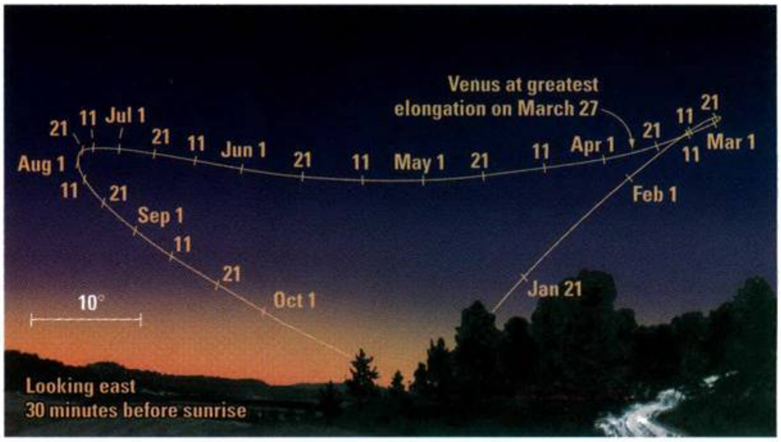
Craig Newswanger

MARCH

S	M	T	W	T	F	S
1	2	3	4	◐	6	7
8	9	10	11	○	13	14
15	16	17	18	19	20	◑
22	23	24	25	26	●	28
29	30	31				

Day	Time (EST)	
1	4 a.m.	The moon passes 1.0° south of Saturn
4	**7 p.m.**	**The moon passes 0.2° north of Aldebaran**
7	5 a.m.	Venus passes 4° north of Neptune (morning)
11	10 a.m.	Mercury passes 1.2° north of Mars (evening)
19	2 a.m.	Venus passes 3° north of Uranus (morning)
	4 a.m.	Juno is at opposition
	11 p.m.	**Mercury is at greatest eastern elongation (19°, evening)**
20	3 p.m.	Equinox (northern spring/southern autumn begins)
23	noon	The moon passes 3° north of Neptune
24	5 a.m.	The moon passes 3° north of Uranus
	2 p.m.	**The moon passes 0.09° north of Venus**
26	**7 a.m.**	**The moon passes 0.8° north of Jupiter**
27	**2 p.m.**	**Venus is at greatest western elongation (47°, morning)**

Inferior Planets Radiate Respect



Mercury and Venus may seem elusive. Banished to a netherworld of perpetual twilight, the solar system's two innermost planets seldom journey far from the sun in our sky. Try as they might to climb away from the solar glare, they often manage only an hour or so of solace in the night, perhaps a few hours in Venus's case, before succumbing to an evening horizon or the dawn of a new day.

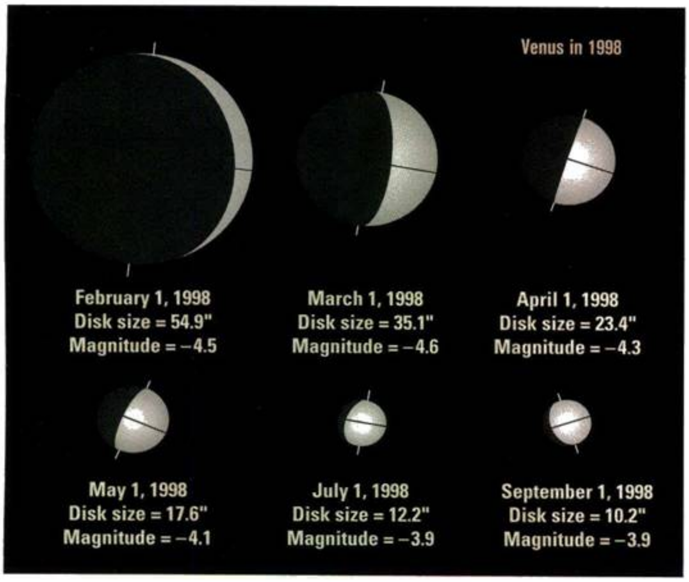
Each planet is an ultimate victim of circumstance. They can never appear during the dead of night because they lie inside Earth's orbit. Planets that orbit outside of Earth's path around the sun, such as Mars and Jupiter, often undergo so-called oppositions. That's when Earth lies directly between them and the sun. During opposition, a planet rises in the east at sunset, lies highest in the south at midnight, and sets in the west at sunrise. Opposition is the best time to see the outer planets.

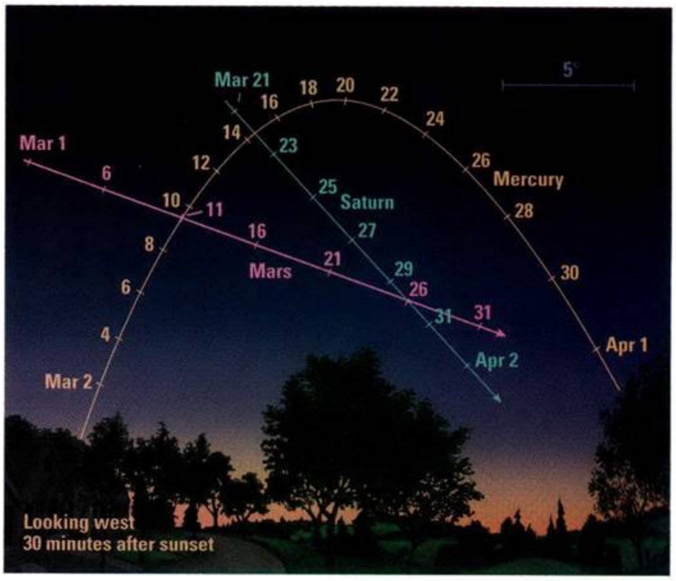
But because Mercury and Venus range inside Earth's orbit, neither can come to opposition in Earth's sky. Their apparent travels trace long arcs along the fringed borders of dawn and dusk. This month sees Venus climb to its highest position in the predawn sky. Visible for a couple hours before sunrise, it shines at magnitude –4.5. Mercury, on the other hand, climbs to its highest and brightest (magnitude –0.2) above the western horizon on March 19/20. These "greatest elongations" are the best time to view the inner planets.

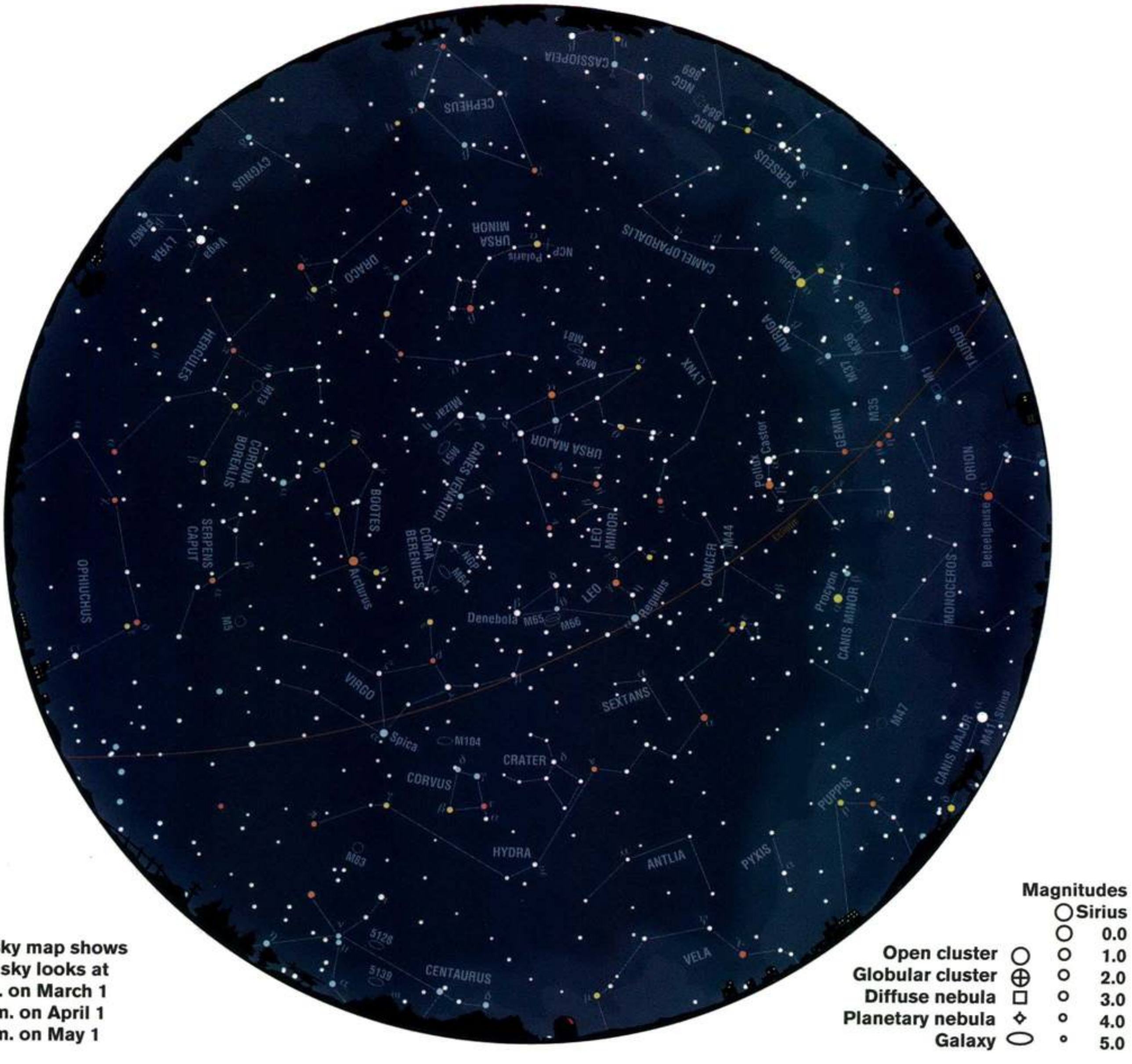
Before you empathize too much with Mercury and Venus, which astronomers have even ignominiously dubbed the "inferior planets" for their position in the solar system, consider one thing. Through a telescope, the two offer something no outer planet can match: phases. This month Venus and Mercury vary between gibbous and crescent as our earthbound viewing perspective varies relative to their orbital meanderings. Another honor; this one for Venus. It often glows as the brightest object in the entire sky, save the sun and moon, thanks to a cloud-thick atmosphere that reflects more than 70 percent of the sunlight that strikes it back into space.

George Livadaras

Brilliant Venus and Mercury (to its lower right) grace the western twilight sky in May 1994.


Venus in 1998
February 1, 1998
Disk size = 54.9"
Magnitude = −4.5
March 1, 1998
Disk size = 35.1"
Magnitude = −4.6
April 1, 1998
Disk size = 23.4"
Magnitude = −4.3
May 1, 1998
Disk size = 17.6"
Magnitude = −4.1
July 1, 1998
Disk size = 12.2"
Magnitude = −3.9
September 1, 1998
Disk size = 10.2"
Magnitude = −3.9




CASSIOPEIA
CEPHEUS
NGC 869
NGC 884
PERSEUS
CYGNUS
M57
LYRA
Vega
URSA MINOR
NCP Polaris
DRACO
CAMELOPARDALIS
Capella
AURIGA
M38
M36
M37
M1
TAURUS
HERCULES
M13
M81
M82
LYNX
GEMINI
M35
Mizar
M51
CANES VENATICI
URSA MAJOR
Castor
Pollux
ORION
CORONA BOREALIS
BOOTES
COMA BERENICES
M53
M64
LEO MINOR
CANCER
M44
Betelgeuse
SERPENS CAPUT
Arcturus
LEO
Regulus
Ecliptic
Procyon
CANIS MINOR
MONOCEROS
OPHIUCHUS
M5
Denebola
M65
M66
VIRGO
SEXTANS
M47
CANIS MAJOR
M41
Sirius
Spica
M104
CRATER
CORVUS
PUPPIS
HYDRA
ANTLIA
PYXIS
M83
5128
5139
CENTAURUS
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
1:00 a.m. on March 1
11:00 p.m. on April 1
10:00 p.m. on May 1

APRIL

S	M	T	W	T	F	S
			1	2	◐	4
5	6	7	8	9	10	○
12	13	14	15	16	17	18
◑	20	21	22	23	24	25
●	27	28	29	30		

Day	Time (EDT, after April 5)
1	**3 a.m.** The moon passes 0.2° north of Aldebaran
6	**1 p.m.** Mercury is in inferior conjunction
8	**7 p.m.** Ceres is in conjunction with the sun
13	**8 a.m.** Saturn is in conjunction with the sun
19	**10 p.m.** The moon passes 3° north of Neptune
20	**4 p.m.** The moon passes 3° north of Uranus
22	**Lyrid meteor shower peaks** **10 p.m.** **Venus passes 0.3° north of Jupiter (morning)**
23	**3 a.m.** **The moon passes 0.2° north of Jupiter** **4 a.m.** **The moon passes 0.08° south of Venus**
24	**3 p.m.** The moon passes 0.9° south of Mercury
28	**2 p.m.** **The moon passes 0.4° north of Aldebaran**

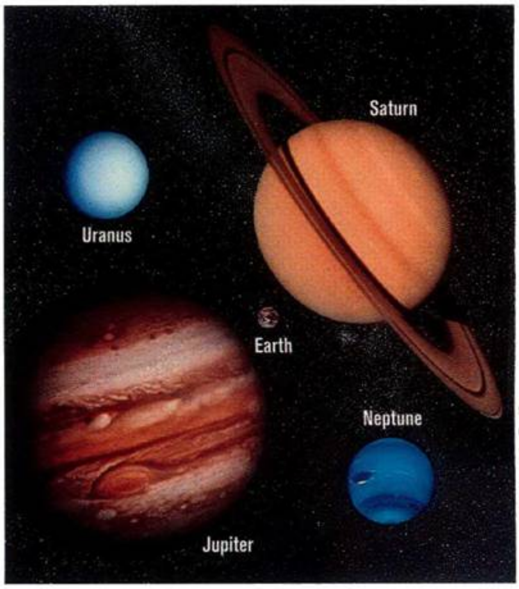
Run a Cosmological Marathon

When April 15 rolls around this year, beat back those tax-day blues by taking a walk through your solar system. That's right; take a snapshot of the planet positions on April 15 at about 8 p.m. local time, reduce it to a manageable scale, and then set it into your neighborhood as a model. The April 15 Planet Model will expand your appreciation of the solar system and, best of all, work off some of the stress that comes from filing at the last minute, again. All you'll need is a compass and a 300-foot tape measure. Have a car standing by for that trip to the nearest star.

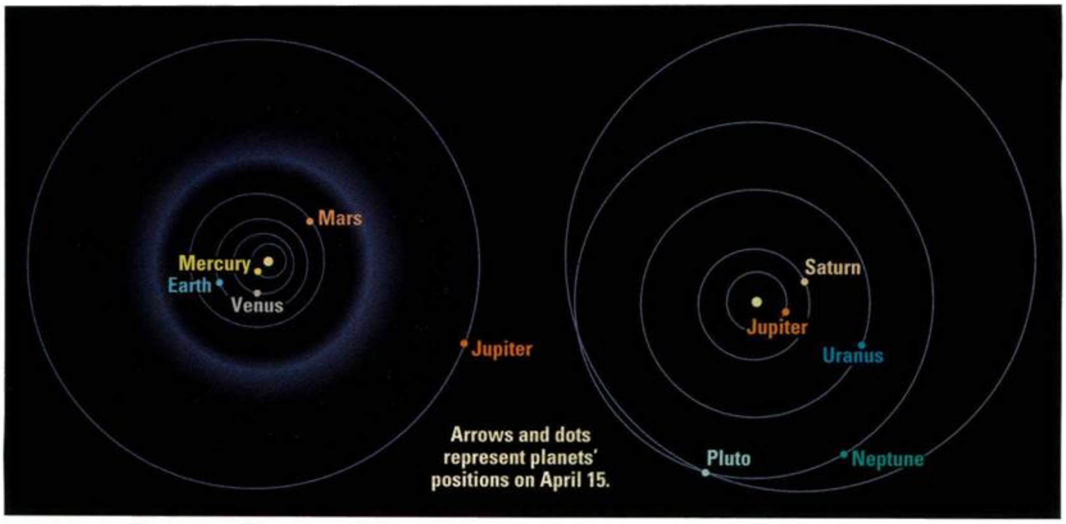
First, define where the center of your model solar system, the sun, lies. Now mark off the direction to each planet. Moving clockwise from 0° north, Jupiter lies at 21°; Uranus, 50°; Neptune, 60°; Venus, 100°; Pluto, 114°; Mercury, 134°; Earth, 154°; Mars, 323°; and Saturn, 337°. Next measure out the distances. If we let 10 feet equal 100 million miles, Mercury would be 4 feet, 2 inches from the sun, followed by Venus at 6 feet, 9 inches from the model's center; then Earth at 9 feet, 4 inches; Mars, 13 feet, 5 inches; Jupiter, 46 feet, 5 inches; Saturn, 86 feet, 10 inches; Uranus, 184 feet, 7 inches; Pluto, 279 feet, 5 inches; and Neptune, 280 feet, 2 inches. By the way, in our model light travels just under a quarter of an inch in one second.

Now, stand in the center and survey your domain. The solar system splays out in essentially all directions around you, from a little more than four feet away to Mercury, out to almost a football field's length for Neptune. Hale-Bopp, the comet that graced the sky a year ago, lies just to the left of Mercury's direction, but is Jupiter's distance away. In about 1,200 years, it will make a U-turn for another dash into the inner solar system from a far point of 3,500 feet. All comets come from a shell of dormant, dirty chunks of ice that surround our solar system out to about 150 miles. Occasionally, the gravity of a passing star starts one or more chunks falling toward the sun to blaze across Earth's skies in a few million years or so. The nearest star to our sun, Proxima Centauri, lies 480 miles distant.

Incidentally, this scale would portray the diameter of our galaxy at about 11 million miles. To make things slightly more manageable, let's shrink the diameter of our real solar system (not the model) down to the size of a quarter. The Milky Way Galaxy would then cover North America.

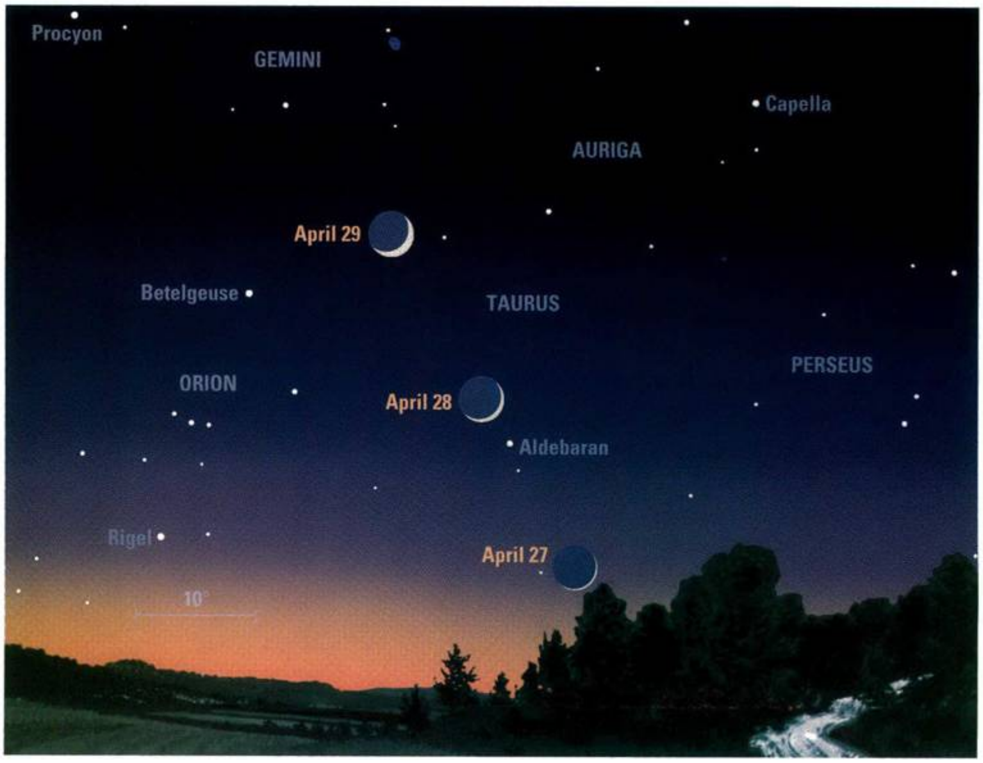


Astronomical Society of the Pacific



Arrows and dots represent planets' positions on April 15.

Glimpse a Young Moon This Spring



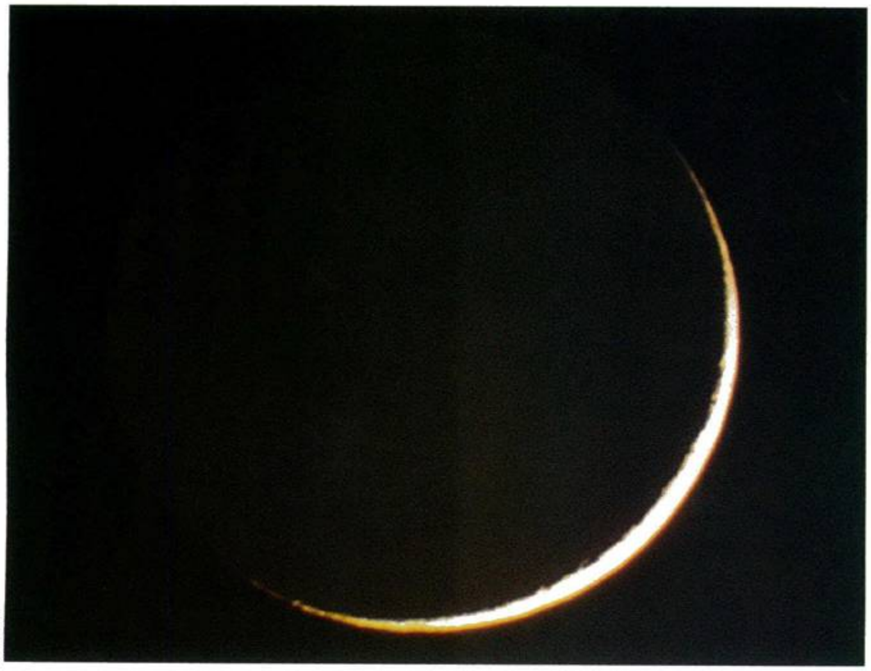
Ask a typical backyard observer what his or her favorite telescopic target is and you'll get a wide range of answers. Some folks like to track down faint galaxies, others prefer the nebulae and clusters of our own Milky Way, while still others enjoy the ever-changing views provided by the planets of the solar system.

But most observers agree on at least one thing: Few naked-eye sights can surpass the beauty of a slender crescent moon hanging amidst the pink, red, and purple colors of a twilight sky. The best time of year to spot such a crescent in the evening sky is during the early spring. That's when the ecliptic, the apparent path of the sun across the sky (and very nearly the same path followed by the moon and planets), makes a steep angle to the western horizon after sunset. Thus the angular separation of the moon from the sun translates mostly into altitude above the horizon.

This year that makes the last few days of March and April the prime times for observing the lunar crescent. In April, new moon (when the moon and sun line up in the sky) occurs on the 26th at 7:41 a.m. EDT. By the time the sun sets that evening at around 8 p.m. local daylight time, the 12-hour-old moon hasn't moved far enough east of the sun to be seen by any but the most eagle-eyed observer.

But the next few days bring a perfect opportunity to spy the young moon. Half an hour after sunset on the evening of the 27th, a breathtakingly slender crescent, just 4 percent lit, is suspended a scant 10° high in the western twilight. (Ten degrees is approximately the angle subtended by your closed fist when held at arm's length.) At the same time the following evening, the moon has climbed to a height of 22° in the west and appears 9 percent lit. And by the 29th, the moon has waxed to 17 percent lit and ascended 33° above the western horizon.

On any of these evenings, also look carefully at the unlit part of the moon. You should see a faint illumination, called earthshine, playing across the dark lunar surface. This comes from our own planet. Whenever the moon shows a crescent phase, the moon "sees" a nearly full Earth. Because Earth is both bigger and more reflective than the moon, lots of light reaches the moon's surface.



Jari Piikki

MAY

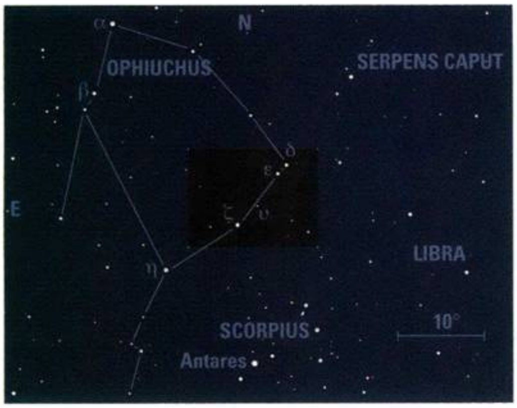
S	M	T	W	T	F	S
31					1	2
◐	4	5	6	7	8	9
10	○	12	13	14	15	16
17	18	◑	20	21	22	23
24	●	26	27	28	29	30

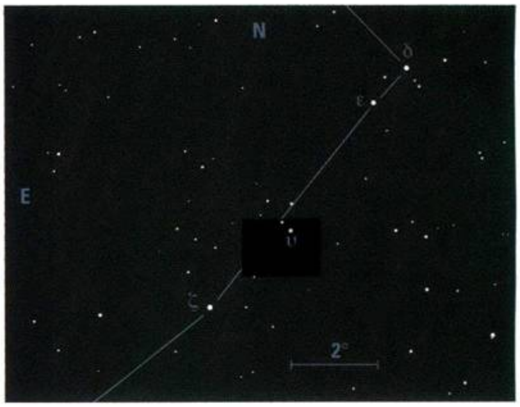
Day	Time (EDT)
4	**1 p.m.** Mercury is at greatest western elongation (27°, morning)
5	**Eta Aquarid meteor shower peaks**
12	**noon** Mercury passes 0.8° south of Saturn (morning) **4 p.m.** Mars is in conjunction with the sun
17	**3 a.m.** The moon passes 3° north of Neptune **11 p.m.** The moon passes 3° north of Uranus
20	**7 p.m.** The moon passes 0.4° south of Jupiter
22	**6 p.m.** The moon passes 1.7° south of Venus
23	**4 a.m.** The moon passes 1.7° south of Saturn
24	**7 a.m.** The moon passes 3° south of Mercury
28	**1 a.m.** **Pluto is at opposition** **10 p.m.** **Venus passes 0.3° north of Saturn (morning)**
31	**midnight** The moon passes 1.0° south of Regulus

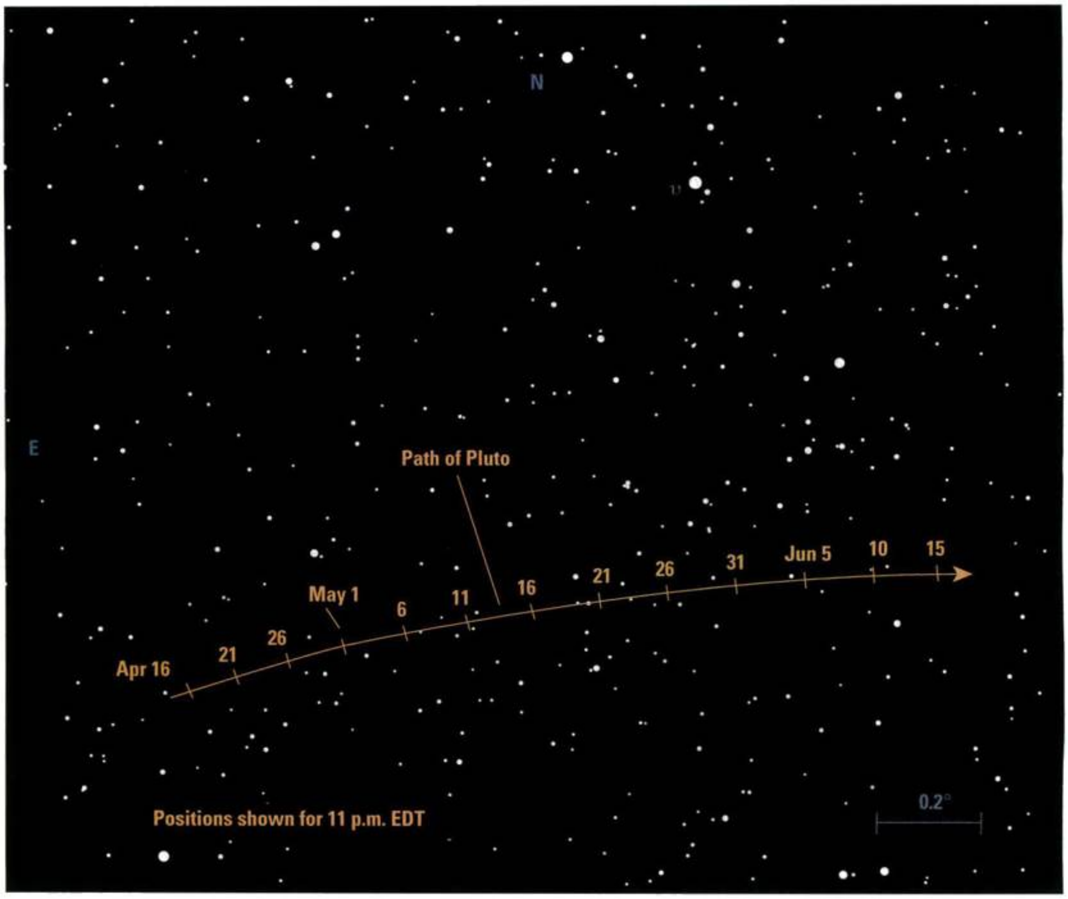
Planet or Not, It's Still Pluto

Questions abound about Pluto. Is it really a planet, or is it some other denizen of the outer solar system? First there's the oddity of a solid planet existing that far from the sun in the first place. Small, terrestrial planets like Mercury, Venus, Earth, and Mars formed only where rock and metal could bask in the young sun's heat 4½ billion years ago and still form solid planets. That same primordial sun would not allow gases like hydrogen and helium to exist so close to it. Instead, they were banished into the colder, outer regions of our solar system to coalesce into the gas-giant planets Jupiter, Saturn, Uranus, and Neptune. And giants they are: 11 Earths, each nearly 8,000 miles wide, would span Jupiter's equator.

And then there's Pluto. Out around Neptune we come across this tiny, solid planet that's smaller than our own moon. Even its orbit is strange, tilted to the plane of our solar







system more than twice as much as the next most inclined planet. A portion of Pluto's path around the sun even falls inside the orbit of Neptune. This fact alone led many planetary scientists to speculate that Pluto was a rogue moon of Neptune.

This notion lingered until 1978, when astronomers discovered an orbiting moon, since named Charon, that was about half as big as the planet itself. Even if tiny Pluto had managed to finesse an escape from Neptune, planetary dynamicists reasoned, making the break with an orbiting moon intact would have bordered on the miraculous. Or does the Pluto/Charon duo bear silent witness to some awesome cosmic collision?

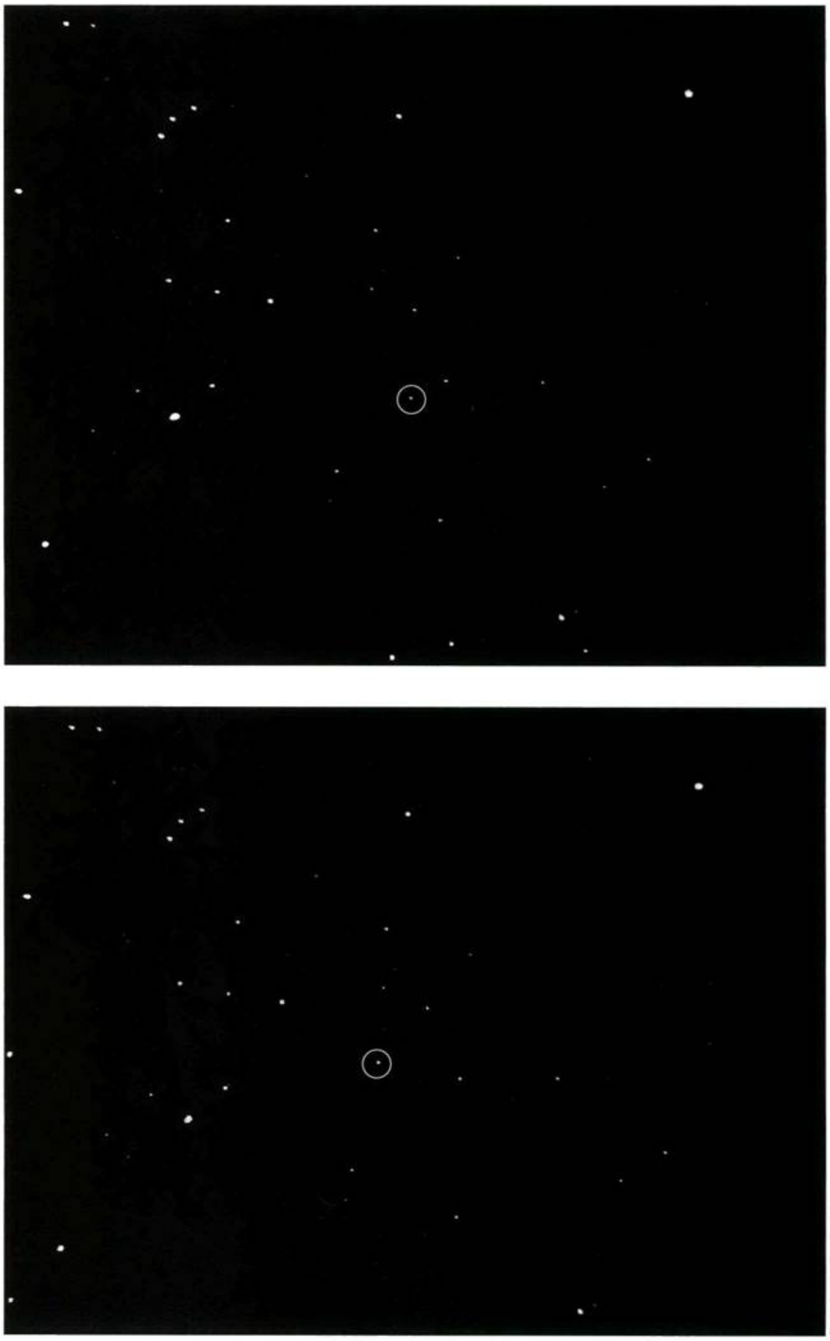
As if to save the day, a new theory on Pluto's genesis has emerged in the 1990s. The planet could be the largest in a new family of solar system members called Kuiper Belt objects. These dark, lumbering chunks of icy rock orbit outside the realm of the gas giants, but inside the fringes of the Oort Cloud, a shell of comets that extends almost a third of the way to the nearest star. So far several dozen Kuiper Belt objects have been logged in orbits not unlike Pluto's. This begs the question of whether other, undiscovered Plutos sail through the darkness beyond the known planets.

The mother of all this speculation comes to opposition on May 27/28, when Pluto lies opposite the sun in our sky and shines at its brightest for the year. "Brightest" is a relative term, however. You'll want to use at least an 8-inch telescope to glean this 13.7-magnitude point of light. Although veteran observers have seen Pluto in a 6-inch scope under excellent conditions, an 8-inch or larger scope will pull in enough extra light to significantly increase your chances of locating it.

You also need to pick an observing site far removed from the lights of the city. In a competition between streetlights and the feeble glow of Pluto, the planet will invariably lose. Also choose a time when the harsh glare from the moon won't interfere. Your best opportunity comes within a week or so of new moon, which this month fortuitously arrives on the 25th, just a few days before Pluto's opposition.

Throughout the month, Pluto moves slowly westward against the background stars of western Ophiuchus, near that constellation's border with far northern Scorpius. To find Pluto, first locate the 3rd-magnitude stars Delta (δ), Epsilon (ε), and Zeta (ζ) Ophiuchi using the naked-eye finder chart at the upper left of the facing page. This stellar trio lies roughly 20° due north of Antares, the 1st-magnitude heart of Scorpius the Scorpion.

From there, use your naked eye or binoculars to zero in on the 5th-magnitude star Upsilon (υ) Ophiuchi, located a little less than halfway from Zeta to Epsilon. Upsilon serves as the jumping off point for you to starhop to Pluto's field using the telescopic finder chart at the bottom of the facing page.



Both photos: Paul Roques

The slow motion of Pluto becomes apparent over the course of a couple of nights. To confirm a sighting of the faint planet, simply look for the point of light that changes position.

That chart shows Pluto's position at 11 p.m. EDT (8 p.m. PDT) from mid-April to mid-June, although Pluto moves so slowly that you won't be able to detect its motion over the course of a single night. The chart includes stars as faint as magnitude 14.1, so you should be able to discern Pluto from the background stars. If you can't place the planet against the stellar backdrop, sketch the field and return to it a day or two later. Any "star" that has moved is not a star after all, but enigmatic Pluto.

JUNE

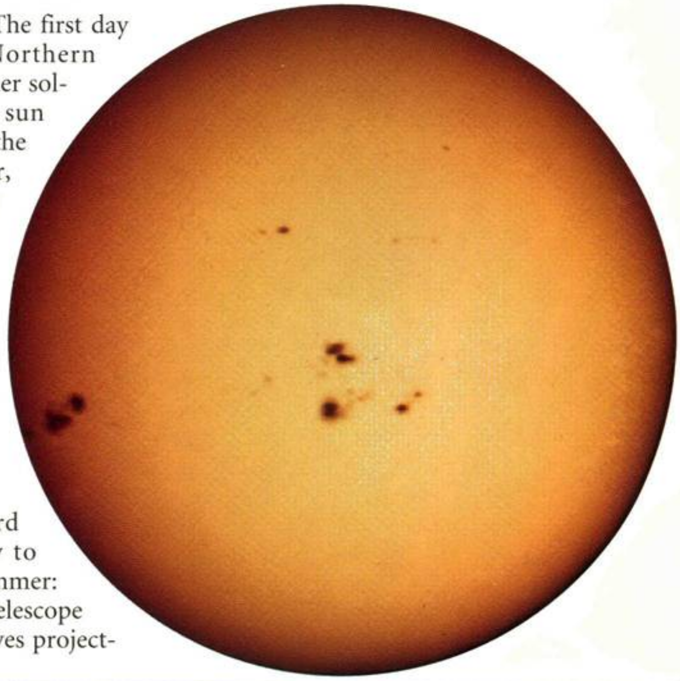
S	M	T	W	T	F	S
	◐	2	3	4	5	6
7	8	9	○	11	12	13
14	15	16	◑	18	19	20
21	22	●	24	25	26	27
28	29	30				

Day	Time (EDT)
9	3 p.m. Vesta is in conjunction with the sun
10	3 a.m. Mercury is in superior conjunction
13	8 a.m. The moon passes 2° north of Neptune
14	4 a.m. The moon passes 3° north of Uranus
17	7 a.m. **The moon passes 0.8° south of Jupiter**
19	4 p.m. The moon passes 2° south of Saturn
21	10 a.m. Solstice (northern summer/southern winter begins) 10 a.m. The moon passes 3° south of Venus
22	10 a.m. **The moon passes 0.4° north of Aldebaran**
25	9 a.m. The moon passes 5° south of Mercury
27	7 a.m. Mercury passes 5° south of Pollux (evening)
28	8 a.m. The moon passes 0.8° south of Regulus

To an Active Summer Sun

June is the gateway to summer. The first day of summer for those in the Northern Hemisphere, aptly called the summer solstice, marks a moment when the sun reaches its most northerly point in the sky. For people north of the equator, it's the day that offers the most daylight hours. In the far north, on the Arctic Circle, the summer solstice brings with it a never-ending day; the sun skirts the northern horizon at midnight without setting. The first day of summer also marks the start of the sun's trek south, a journey that culminates on December 21 with the winter solstice.

All this daylight offers backyard observers a perfect opportunity to observe the main attraction of summer: the sun. You can look at it with a telescope in one of two ways. The first involves project-



Nicolas Noiseux

ing the sun's image onto a white piece of cardboard. The second way is to slip a solar filter over the telescope's front opening to block out all of the sun's harmful heat and light before it enters the telescope, letting you scrutinize the solar surface directly through an eyepiece.

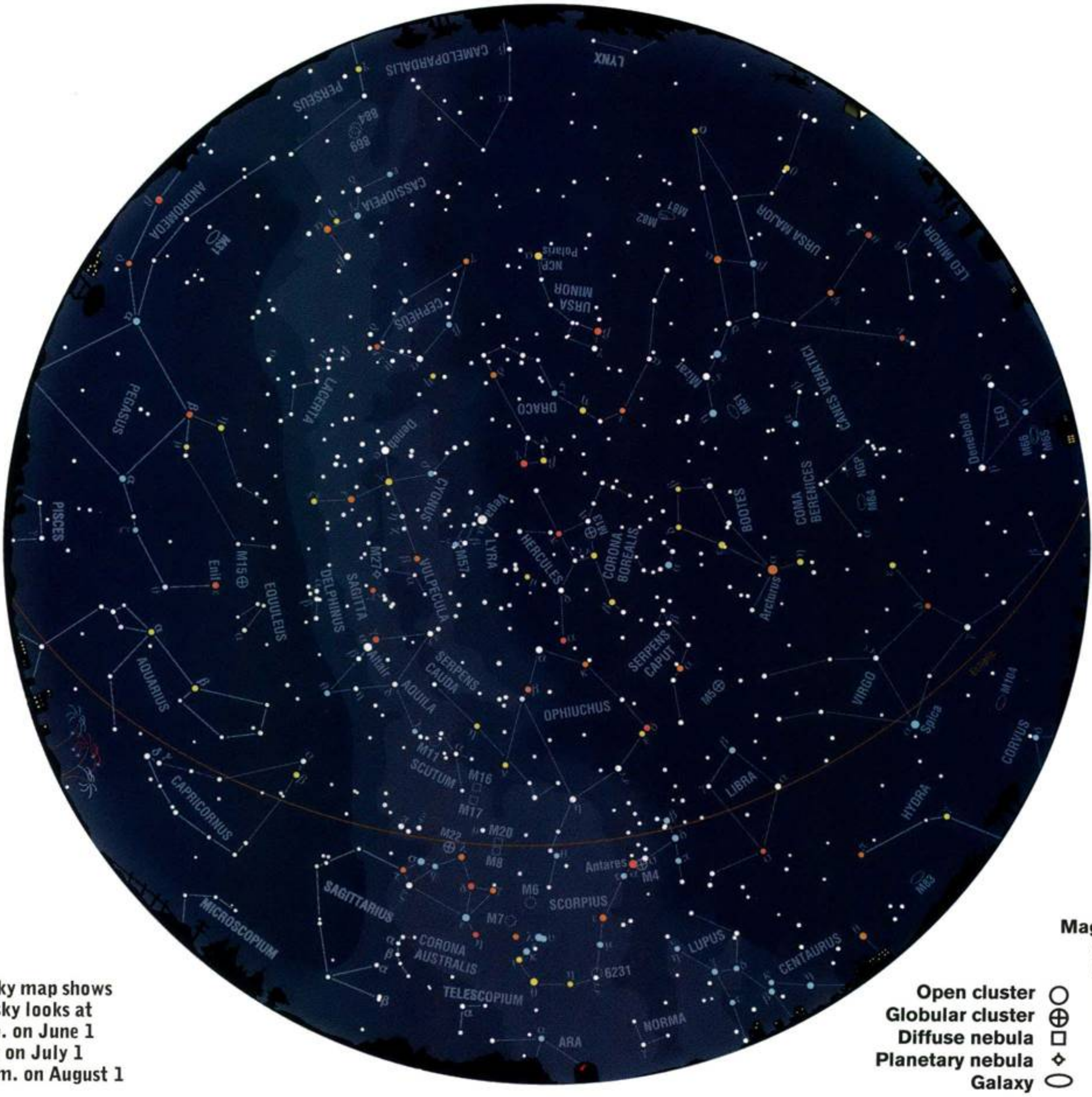
And just what can you see on the sun?

For one, 1998 sees the sun coming out of a period of relative quiet. For the past two to three years, its gaseous surface has been mostly free of sunspots. But now that activity's on the upswing, moving toward a peak predicted to occur in 2000, start looking for these Earth-sized, dark splotches that mark areas of the sun's surface some 2,500° F cooler than the surrounding gases. You might also notice that the sun's entire face looks granular. These granules are bubbling, 600-mile-wide cells of rising gas. Here and there you can sometimes see bright, white "clouds" called faculae on the sun's face. Faculae appear more noticeable near the sun's edge, or limb, because that region is darker than the rest of the sun's surface. This limb darkening comes about because we see higher, cooler layers of the sun's atmosphere when we look toward the limb.

The rising level of solar activity brings with it another observing treat, this one visible after the sun goes down. Solar flares eject protons and electrons that reach Earth in just a few days. Our planet's magnetic field then funnels these particles into the atmosphere. They give up some of their energy to the atmosphere's atoms and molecules, which then reradiate it as light. This majestic light show, known as the aurora or northern lights, ranks as one of the most beautiful sights to grace the night sky.

As solar activity rises this year, the sun should teem with spots (top). Aurorae (bottom) should be another sign of this heightened activity.

Sun photo by William Sterne, Jr.


CAMELOPARDALIS
LYNX
PERSEUS
884
869
CASSIOPEIA
ANDROMEDA
M31
Polaris
NCP
URSA MINOR
M82
M81
URSA MAJOR
LEO MINOR
CEPHEUS
LACERTA
DRACO
Mizar
M51
CANES VENATICI
Denebola
LEO
M66
M65
PEGASUS
Deneb
CYGNUS
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
BOOTES
COMA BERENICES
NGP
M64
PISCES
Enif
M15
EQUULEUS
DELPHINUS
SAGITTA
M27
VULPECULA
Arcturus
Altair
SERPENS CAUDA
AQUILA
SERPENS CAPUT
M5
VIRGO
Spica
Ecliptic
M104
CORVUS
AQUARIUS
OPHIUCHUS
M11
SCUTUM
M16
M17
LIBRA
CAPRICORNUS
M22
M20
M8
Antares
M4
HYDRA
M6
SCORPIUS
M83
M7
SAGITTARIUS
MICROSCOPIUM
CORONA AUSTRALIS
LUPUS
CENTAURUS
6231
TELESCOPIUM
NORMA
ARA

The all-sky map shows how the sky looks at
2:00 a.m. on June 1
midnight on July 1
10:00 p.m. on August 1

Magnitudes
○ Sirius
○ 0.0
○ 1.0
○ 2.0
○ 3.0
○ 4.0
○ 5.0

Open cluster ○
Globular cluster ⊕
Diffuse nebula □
Planetary nebula ✧
Galaxy ⬭

JULY

S	M	T	W	T	F	S
			◐	2	3	4
5	6	7	8	○	10	11
12	13	14	15	◑	17	18
19	20	21	22	●	24	25
26	27	28	29	30	◐	

Day Time (EDT)

3 **1 a.m.**
Venus passes 4° north of Aldebaran (morning)

10 **2 p.m.**
The moon passes 2° north of Neptune

11 **9 a.m.**
The moon passes 3° north of Uranus

14 **3 p.m.**
The moon passes 1.0° south of Jupiter

16 **11 p.m.**
Mercury is at greatest eastern elongation (27°, evening)

17 **1 a.m.**
The moon passes 2° south of Saturn

19 **5 p.m.**
The moon passes 0.3° north of Aldebaran

21 **8 a.m.**
The moon passes 4° south of Venus
11 p.m.
The moon passes 5° south of Mars

23 **4 p.m.**
Neptune is at opposition

25 **10 a.m.**
The moon passes 2° north of Mercury
5 p.m.
The moon passes 0.7° south of Regulus

28 **Southern Delta Aquarid meteor shower peaks**

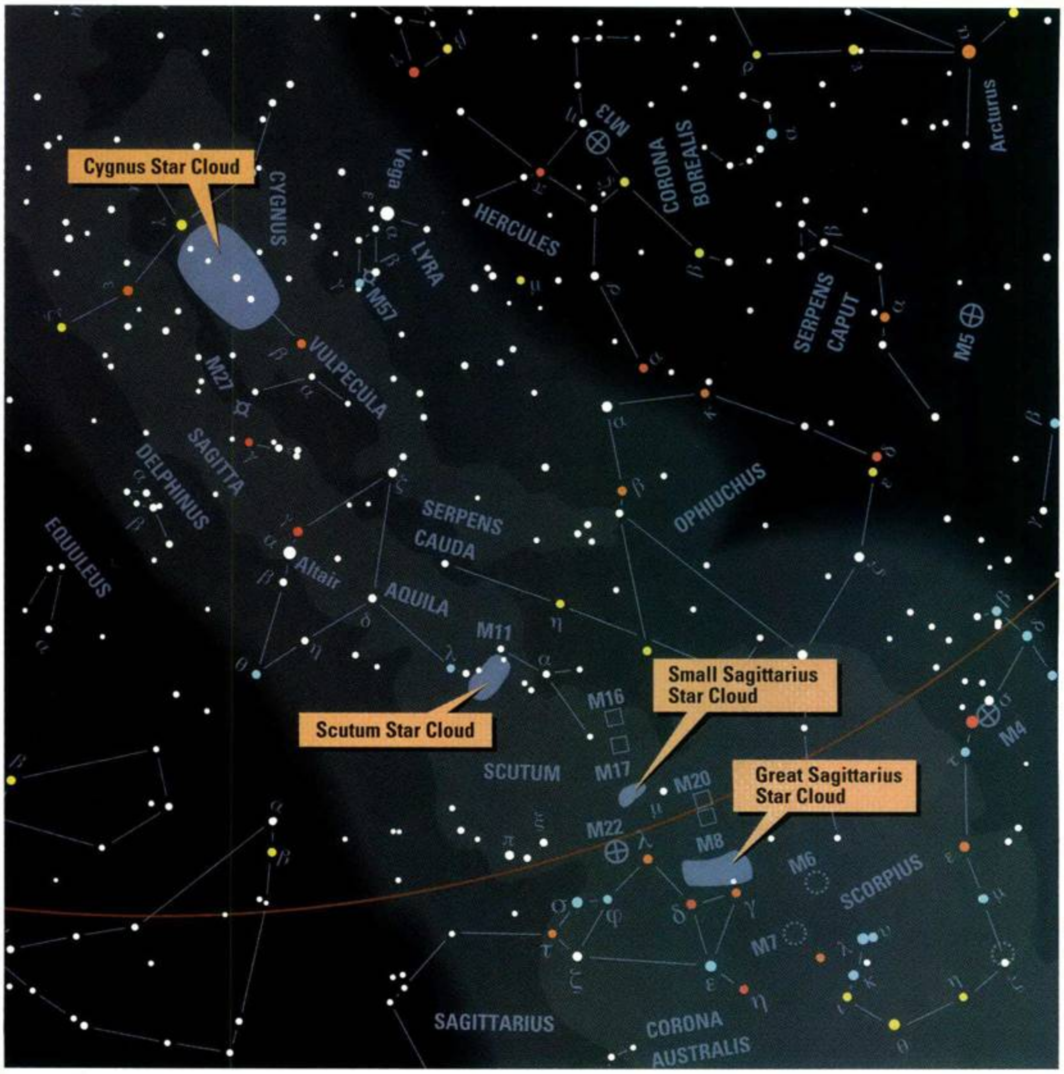
Viewing Our Home Galaxy

Sultry July evenings compel us to pull up a chair and enjoy one of the greatest shows the night sky can offer. It is the one put on by the summer Milky Way, a luminous band of light that stretches overhead from the north all the way to the southern horizon. It's best taken in from an observing site far away from city lights, where the eye is greeted by patches of glowing gas and blots of obscuring dust, all set against a misty backdrop of millions of unresolved stars. Spread out before us is the home galaxy that contains our sun and a couple hundred billion other stars, a relatively typical spiral galaxy some 100,000 light-years in diameter.

From our vantage point on Earth, when we view the luminous band of the Milky Way we are seeing the galaxy edge-on, along its plane, from the inside. One naked-eye feature makes this plainly apparent. A dark void begins at the southern end of Cygnus and opens to its widest in Aquila and Ophiuchus. This is the Great Rift, a break in the Milky Way's soft glow caused by dust that lies along our line of sight.

Gaps in the dust allow us to see other features in our home galaxy. Between the teapot of Sagittarius and the stinger of Scorpius, and south of the Lagoon Nebula (M8), lies the Great Sagittarius Star Cloud. The cloud is actually a hub of stars that surrounds our galaxy's center some 30,000 light-years from Earth.

Moving up the Milky Way's spine to an area 3° north-northeast of Mu (μ) Sagittarii brings into view the Small Sagittarius Star Cloud, which lies some 16,000 light-years away. A rather fortuitously placed window in the dust allows us to see the cloud, part of the innermost arm that curves away along our line of sight around the galaxy's center.



Cygnus Star Cloud
CYGNUS
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
SERPENS CAPUT
Arcturus
M5
VULPECULA
M27
SAGITTA
DELPHINUS
EQUULEUS
Altair
AQUILA
SERPENS CAUDA
OPHIUCHUS
M11
Scutum Star Cloud
SCUTUM
M16
M17
Small Sagittarius Star Cloud
M20
M8
M22
Great Sagittarius Star Cloud
M6
M7
M4
SCORPIUS
SAGITTARIUS
CORONA AUSTRALIS

Continuing to move ever northward along the Rift takes us to the Scutum Star Cloud, tucked between Alpha (α) Scuti and Lambda (λ) Aquilae. This tiny patch of light echoes the view of the Small Sagittarius Star Cloud, except this time we're seeing the Sagittarius-Carina Arm of our galaxy, a spiral arm positioned between our sun's arm and the inner arm, curving away into the distance.

Incidentally, most of the deep-sky objects scattered throughout Sagittarius, Scutum, and Scorpius lie within the Sagittarius-Carina Arm. The naked-eye stars that make up these constellations (as well as many of the others in the sky) reside in the Orion Arm, the same arm that harbors our sun.

One final star cloud, one of the sky's biggest, glimmers high in the summer Milky Way, in the constellation Cygnus the Swan. Here we view down the length of the Orion Arm as it arcs around the galaxy's center. Consequently, millions of stars merge into a soft glow that encompasses the entire central region of Cygnus's Northern Cross.

John Nemy/The Pacific Observatory

View a Bright Summertime Asteroid

Everyone enjoys viewing the swirling cloud bands of Jupiter, the gossamer rings of Saturn, and the shifting sands of Mars. These and the other major planets offer real worlds to explore and, though they may not show the rapid changes we've come to expect from the dynamic Earth, they provide hours of pleasure for telescope owners.

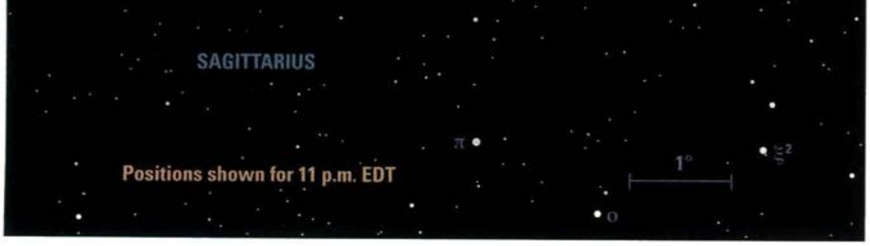
The minor planets, as their name suggests, bring a more subtle reward. The goal is not to view changing weather patterns or intricate detail, the goal is simply to see. For these relatively small objects appear as only points of light adrift in a vast sea of other points of light – the stars. (In fact their other name, asteroids, literally means "starlike.")

Astronomers know of more than ten thousand minor planets, ranging in size from the 600-mile-diameter Ceres to chunks of rock less than a mile across. Only one, Vesta, ever gets bright enough to see with the naked eye, and then just barely. To catch a glimpse of any of the others requires binoculars or, more often than not, a good-sized telescope.

This year one of the less well-known asteroids, Iris, puts in a nice appearance. When at its best during July, it glows at magnitude 8.6, well within range of binoculars or a small scope. The English astronomer John Russell Hind discovered this 130-mile-wide asteroid in 1847, making it the seventh asteroid found.

You can locate Iris traversing northern Sagittarius during the course of July, north of the Teaspoon asterism formed by Pi (π), Omicron (o), and Xi (ξ) Sagittarii. Unfortunately, this area lies within the band of the Milky Way, so lots of stars will compete with Iris for your attention. The best night to spot it may be July 6, when the minor planet passes just 5' north of the 4th-magnitude star Rho¹ (ρ¹) Sagittarii.

The finder chart at left shows stars as faint as magnitude 9.0, so you should be able to pinpoint Iris by comparing the chart to the view in your telescope. If you aren't convinced you've located it, sketch or photograph the stars you see in your field of view and then return to the same field a night or two later. The "star" that has moved is Iris.



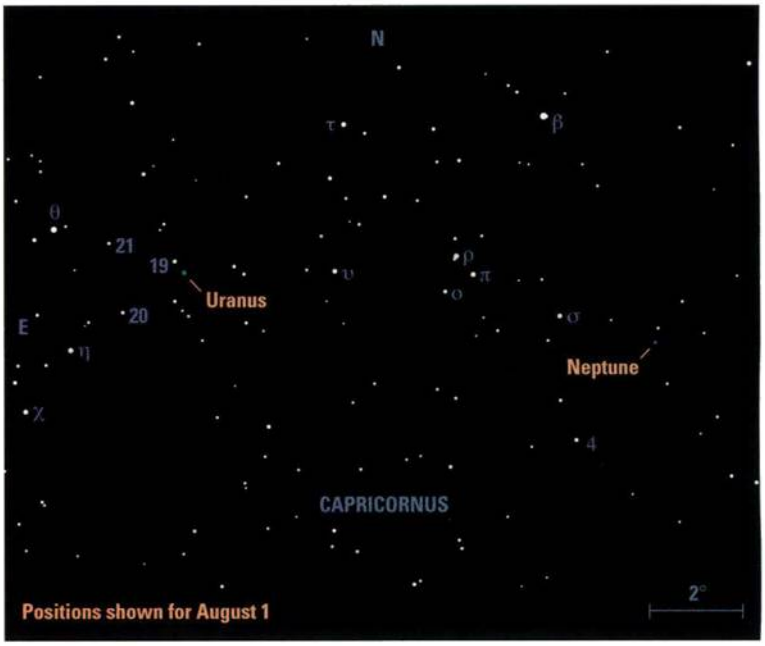
Positions shown for 11 p.m. EDT

AUGUST

S	M	T	W	T	F	S
◐	31					1
2	3	4	5	6	○	8
9	10	11	12	13	◑	15
16	17	18	19	20	●	22
23	24	25	26	27	28	29

Day	Time (EDT)
3	3 a.m. **Uranus is at opposition**
4	11 p.m. **Venus passes 0.8° south of Mars (morning)**
10	8 p.m. The moon passes 0.9° south of Jupiter
12	**Perseid meteor shower peaks**
13	8 a.m. **The moon passes 2° south of Saturn** 8 p.m. Mercury is in inferior conjunction
15	11 p.m. The moon passes 0.2° north of Aldebaran
19	4 p.m. The moon passes 4° south of Mars
20	10 a.m. **The moon passes 3° south of Venus**
21	10 p.m. **Annular solar eclipse (visible between mainland Asia and Australia)**
25	7 p.m. **Mercury passes 3° south of Venus (morning)**
31	5 a.m. **Mercury is at greatest western elongation (18°, morning)**

Thank Your Dim Giants



Positions shown for August 1

Everything just seems big for the gas-giant planets. It would take 11 Earths to span Jupiter's equator. Saturn is a bit smaller, but it comes with a ring system more than 20 Earth-diameters wide. These two planets even shine brightly in our night sky: Jupiter at magnitude –2.9 when brightest in 1998, Saturn at magnitude 0.0. Such conspicuousness immediately landed them names from the Roman pantheon of gods.

But Uranus and Neptune, though large by Earth standards, are small as gas giants come and relative newcomers to the planetary scene. Each planet, almost identical in size, measures only 35% the diameter of Jupiter. Their smaller size and greater distance from the sun conspired to keep them hidden from earthbound observers until the 18th and 19th centuries. Uranus, first glimpsed in 1781, barely manages to climb to naked-eye visibility at magnitude 5.7, which it does on August 3. Fainter, more distant Neptune, discovered in 1846 after its position was predicted by mathematicians, only musters a magnitude of 7.8 on July 23.

The easier of the two to find is Uranus. Look for it among the stars of Capricornus, glowing as a blue-green orb through a small telescope or binoculars. This color alone distinguishes

Terence Dickinson

Uranus (right) and Neptune (left) have appeared close together for the past several years.

Uranus from white Jupiter and golden-colored Saturn. Where hydrogen and helium make up the vast majority of the gas-giants' atmospheres, methane is a significant constituent found on Uranus. Methane gas scatters sunlight to make the uranian globe glow green. Neptune also sports a greenish-blue atmosphere, but you wouldn't know it from looking through a pair of binoculars. Its feeble light becomes apparent only in a small telescope; look for it in Capricornus, to the west of Uranus.

As you hunt down these behemoths of the dark, consider the role our gas-giant cousins played in allowing life to get a toehold on Earth. Their massive gravitational effects either deflected or sucked up flotsam left over from the formation of our solar system. Too much lingering debris, and the evolutionary clock of life on Earth would have been reset after each huge impact. We witnessed this vital role at work in 1994 when Jupiter captured, and then swallowed, Comet Shoemaker-Levy 9. Uranus and its family of moons orbit side-on to the rest of the solar system, the signature of a massive hit that knocked the entire system out of kilter millions of years ago.

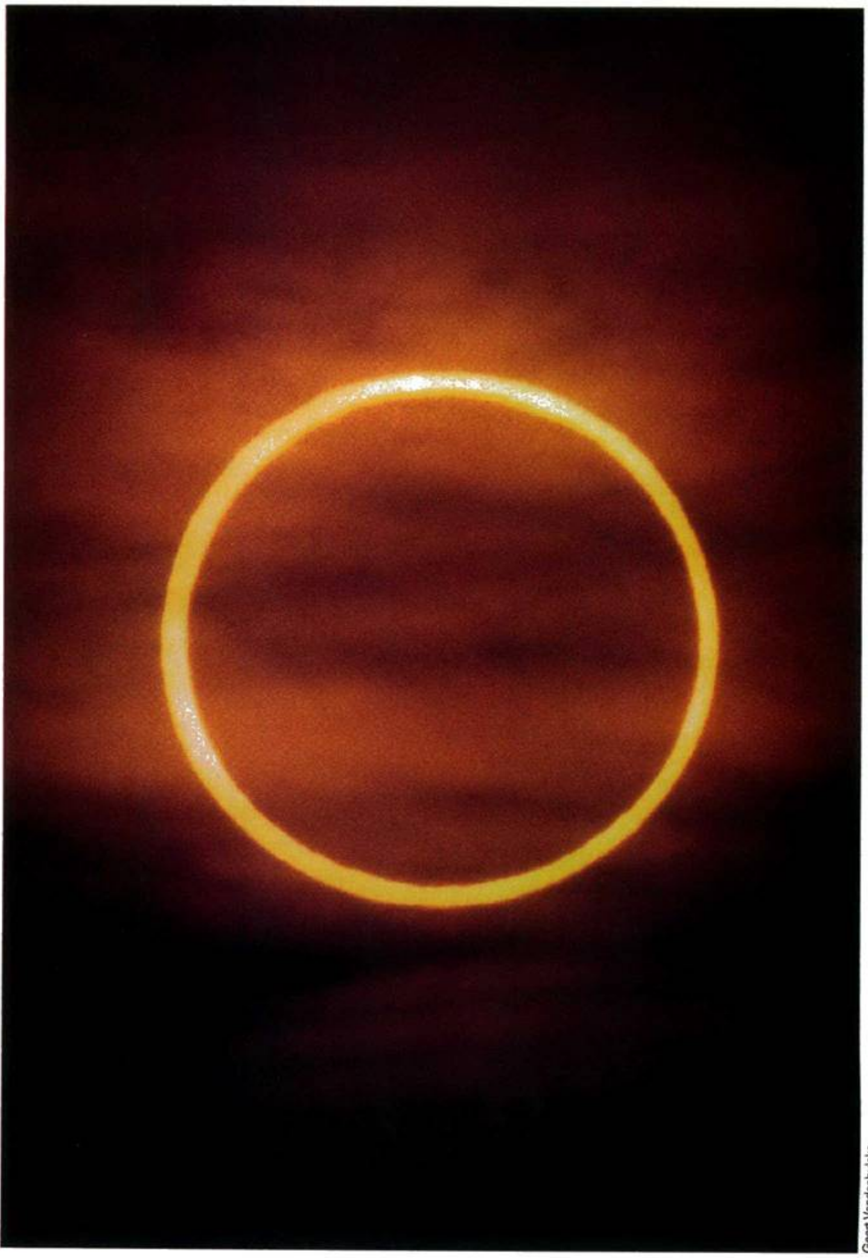
Ring of Fire: The Year's Second Solar Eclipse

When people think of solar eclipses, they usually envision fiery red prominences leaping from the sun's limb or the gauzy, pearly-white corona that forms the outer atmosphere of our star. Spectacular? Of course. But the awe-inspiring beauty of a total eclipse shouldn't blind you to the immense joys of viewing other solar eclipses.

This year provides globe-trotting eclipse aficionados with a great opportunity to compare a total eclipse with an annular eclipse. We already discussed the total eclipse that will track across northern South America and the Caribbean Sea on February 26. On August 22, the moon's shadow once again touches Earth, treating residents of and visitors to the islands between Australia and mainland Asia to an annular eclipse.

During an annular eclipse, the moon lies a little farther from Earth than during a total eclipse. That means the moon's disk appears slightly smaller in the sky – not quite big enough to cover the sun's entire surface. Instead, a bright ring, or annulus, of sunlight remains around the moon. In this month's eclipse, the moon covers 97 percent of the solar diameter.

The moon's shadow begins its journey across Earth's surface in the Indian Ocean. From there the track heads east, first hitting land in Sumatra, followed by Malaysia and then northern Borneo. After Borneo, the path of annularity lies mostly over open water. Maximum eclipse occurs about 100 miles north of New Guinea, where annularity lasts for 3 minutes and 14 seconds.



Geert Vandenbulcke

SEPTEMBER

S	M	T	W	T	F	S
		1	2	3	4	5
○	7	8	9	10	11	◑
13	14	15	16	17	18	19
●	21	22	23	24	25	26
27	◐	29	30			

Day Time (EDT)

6 **6 a.m.**
Venus passes 0.8° north of Regulus (morning)
midnight
The moon passes 0.5° south of Jupiter

7 **3 p.m.**
Mercury passes 0.8° north of Regulus (morning)

9 **2 p.m.**
The moon passes 2° south of Saturn

10 **8 p.m.**
Mercury passes 0.4° north of Venus (morning)

12 **4 a.m.**
The moon passes 0.3° north of Aldebaran

15 **11 p.m.**
Jupiter is at opposition

16 **1 a.m.**
Pallas is at opposition

17 **8 a.m.**
The moon passes 2° south of Mars

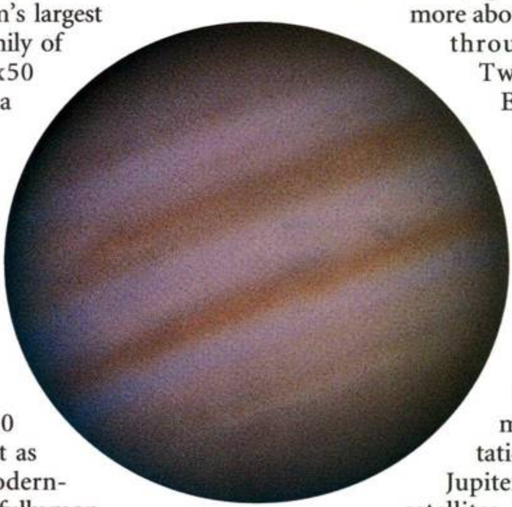
18 **7 a.m.**
The moon passes 0.6° south of Regulus

23 **2 a.m.**
Equinox (northern autumn/southern spring begins

25 **4 p.m.**
Mercury is in superior conjunction

30 **3 p.m.**
The moon passes 2° north of Neptune

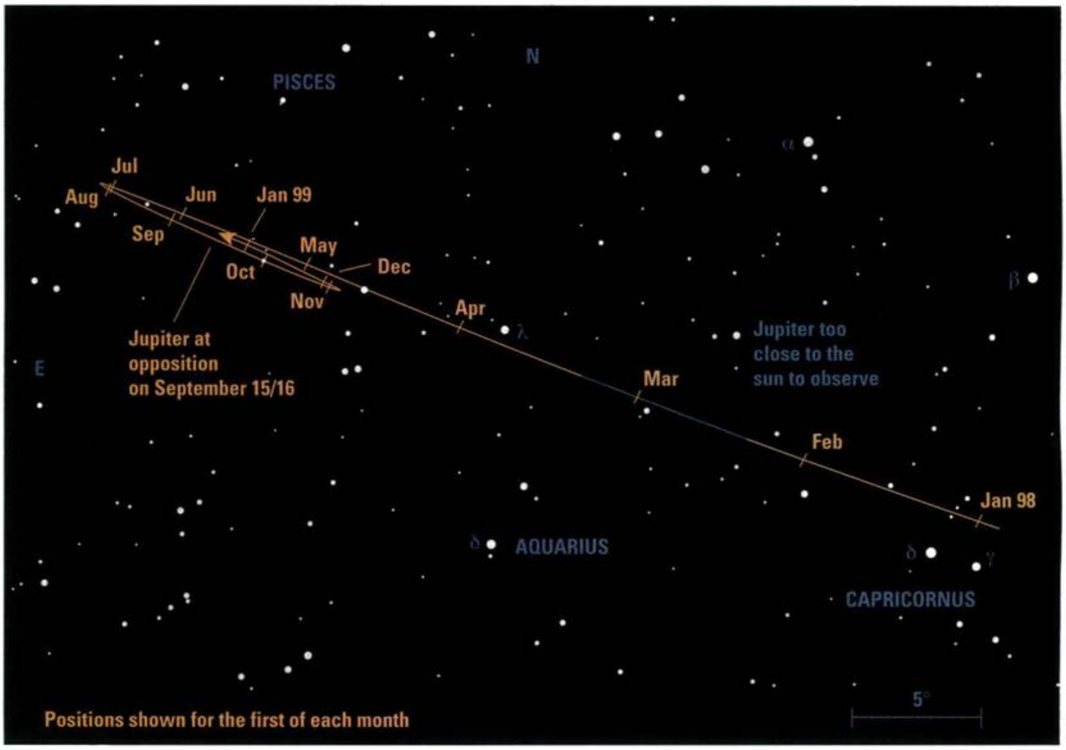
The Light of the Jovian Moons



The crisp autumn air, as well as the lengthening nights, offers a special treat to skywatchers this year. Look low in the east for a bright, creamy-colored luminary that glows with a steady, unblinking light. Aside from Venus in the west at year's end, it's the brightest "star" in the evening sky as 1998 winds down. This is Jupiter, the solar system's largest planet and home to a family of 16 moons. A pair of 7x50 binoculars braced against a wall or tree, or mounted on a tripod, reveals the four biggest moons: Io, Europa, Ganymede, and Callisto.

These are also known as the Galilean satellites, named for the 17th-century Italian astronomer Galileo, who first glimpsed them in 1610 through a telescope about as powerful as a pair of modern-day binoculars. If you carefully monitor the moons each evening, you'll soon discover something else Galileo stumbled upon. The position of each moon changes from night to night. To Galileo, this implied that they orbited Jupiter much like planets orbited the sun. This notion ran contrary to the prevailing opinion that everything in the sky moved around Earth. Galileo's eyes said otherwise; his stubborn insistence eventually landed him under house arrest.

Thanks to a spacecraft named for Galileo that orbits Jupiter today, we know much more about the moons he first saw through his tiny telescope. Two of them, Io and Europa, are among the most fascinating objects in the solar system. Io, the closest of these satellites to Jupiter, sports a face pocked by active volcanos that belch molten sulfur into pools the size of Rhode Island. The moon's interior is kept molten thanks to a gravitational tug-of-war between Jupiter and the other Galilean satellites. Europa shows evidence for a similar process that melted its ice-encrusted surface into a landscape of shifting plates and icebergs. Many scientists believe that this moon is still warm enough to sustain a liquid ocean beneath the icy crust. Thermal vents



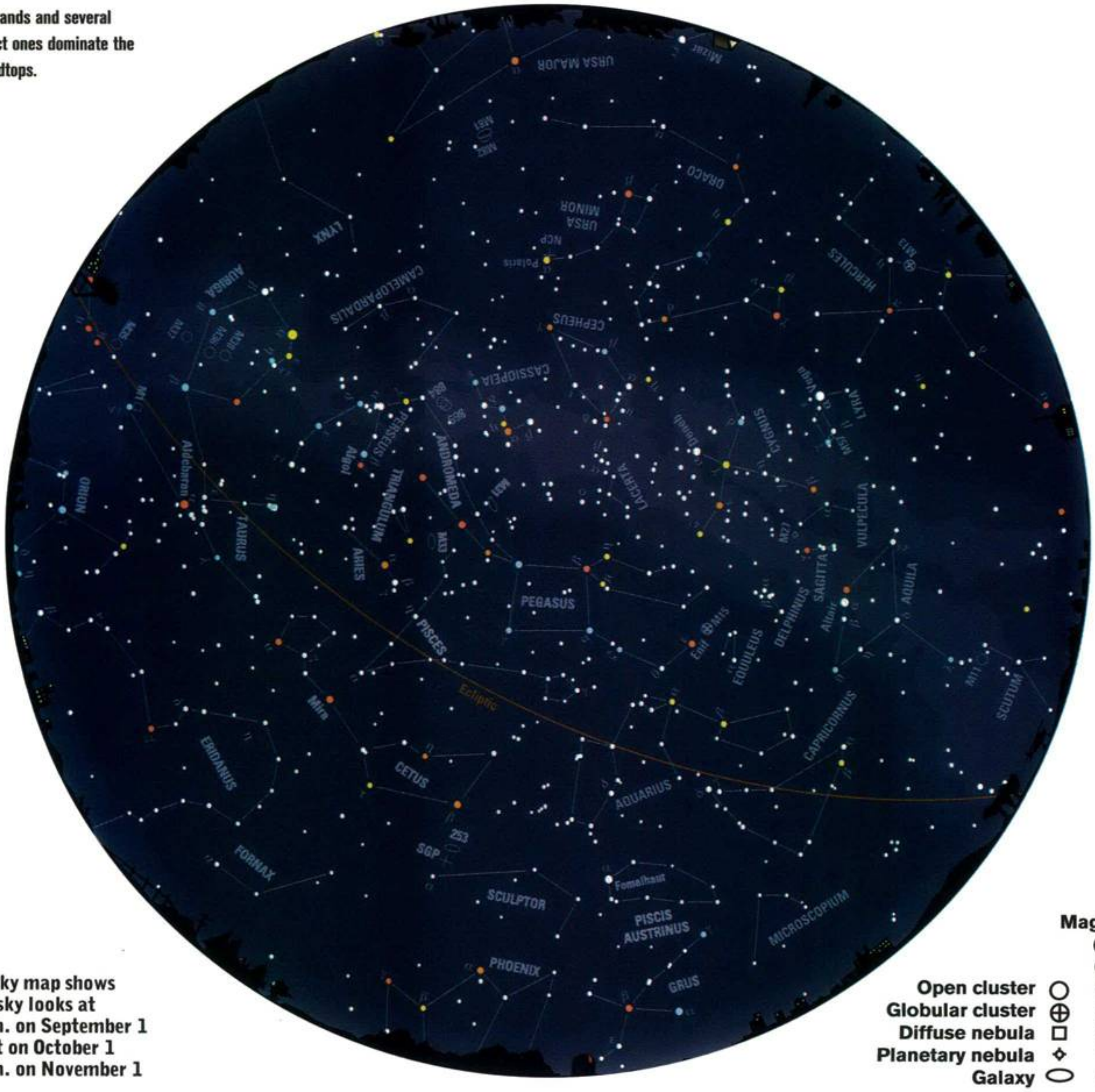
Positions shown for the first of each month deep in Earth's oceans are home to some unique forms of life that eke out an existence without benefit of sunlight. After Mars, Europa just might be the most likely place to look for life outside of our planet.

The remaining two Galilean satellites, Ganymede and Callisto, are intriguing in their own right. Ganymede is our solar system's largest moon and bigger than Mercury. Huge, continent-sized networks of furrows suggest its crust may have been warmer like Europa's, but for the most part today this moon is dormant. Dormancy is definitely the word that best describes Callisto. Its ancient surface has crater piled upon crater, with some of the bigger impacts leaving giant, concentric shatter rings.

But don't think that the moons of Jupiter are all that the planet has to offer. A careful look through a small backyard telescope reveals Jupiter itself to be a riot of atmospheric activity. The most obvious features are the alternating series of dark belts and lighter zones that girdle the planet parallel to its equator. The most prominent of these are the North and South Equatorial Belts, which are separated by the equally noticeable Equatorial Zone. However, when Jupiter looms large in the sky (as it does for several weeks around its September 15 opposition) and seeing conditions are steady, several other belts and zones come into view.

A somewhat more-elusive feature in the cloudtops of Jupiter is the Great Red Spot. This huge high-pressure system in the planet's southern hemisphere has been viewed from Earth for more than 300 years. The name is a slight misnomer, however, because the spot more often appears pink or salmon-colored. You should be able to glimpse the Great Red Spot if you catch it when it's on the hemisphere facing Earth.

Two dark bands and several less distinct ones dominate the jovian cloudtops.
Jack Zeiders


URSA MAJOR
Mizar
DRACO
URSA MINOR
NCP
Polaris
HERCULES
M13
LYNX
CAMELOPARDALIS
CEPHEUS
AURIGA
CASSIOPEIA
PERSEUS
Algol
ANDROMEDA
M31
TRIANGULUM
ARIES
LACERTA
CYGNUS
Deneb
Vega
LYRA
VULPECULA
SAGITTA
DELPHINUS
EQUULEUS
Altair
AQUILA
SCUTUM
M11
ORION
Aldebaran
TAURUS
PEGASUS
PISCES
Ecliptic
Mira
CETUS
ERIDANUS
FORNAX
SGP
253
SCULPTOR
AQUARIUS
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
MICROSCOPIUM
PHOENIX
GRUS

The all-sky map shows how the sky looks at
2:00 a.m. on September 1
midnight on October 1
9:00 p.m. on November 1

Magnitudes
○ Sirius
○ 0.0
○ 1.0
○ 2.0
○ 3.0
○ 4.0
○ 5.0

Open cluster ○
Globular cluster ⊕
Diffuse nebula □
Planetary nebula ✧
Galaxy ⬭

Wrung Out on Ringed Planets

Few things look as breathtaking as Saturn through a telescope. Here's a world unlike any other in our home star system. What makes this planet such a treat to look at is a network of rings that spans 170,000 miles from tip to tip but measures only a few dozen feet thick. For comparison, Saturn's diameter is 75,000 miles, some nine times that of Earth's. The best time to see Saturn and its rings this year happens around October 23, when Earth lies directly between it and the sun. On that night, the Ringed Planet will be up all night for telescopic observation.

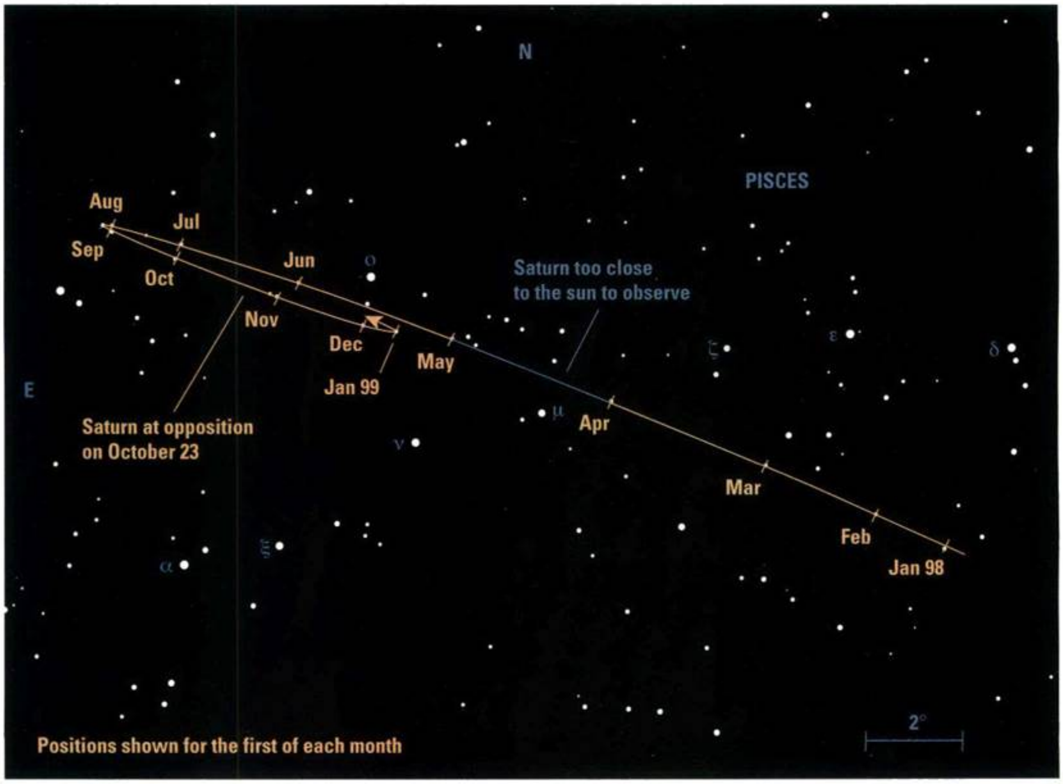
Saturn's rings aren't as solid as they look through a telescope. Seven main rings are actually thousands of ringlets made of ice and rock. This debris never formed an intact moon, thanks to the tidal stresses imposed by Saturn's gravity. Every planet, including Earth, has a so-called "Roche limit" within which smaller material cannot coalesce into a larger satellite.

Prior to 1977, astronomers thought Saturn was unique for its ring system. Now, thanks mostly to spacecraft, we know that all of the other gas-giant planets harbor rings. Oddly enough, the solar system's largest planet, Jupiter, has the most ethereal ring complex of all. Where the stuff that makes up Saturn's rings ranges in size from grains of sand to house-sized boulders, Jupiter's wispy rings have more in common with smoke particles.

Mark Wainright

Spacecraft have also revealed that the rings are much more than lots of junk orbiting a host planet. Some of Saturn's ringlets get herded into shape by pairs of "shepherd" moons. Still other ringlets are only temporary and slowly drizzle into the upper atmospheres of their host worlds in less than a few hundred million years. This suggests that planetary rings are constantly getting replenished by the collision of tiny moons within them or by the influx of interplanetary meteoroids. Jupiter's single, tenuous ring might even owe its existence to volcanic eruptions on Io, one of four large moons that orbit the planet.

Regardless, it's only the planetary rings around Saturn that greet backyard observers.


N
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PISCES
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Saturn too close to the sun to observe
Saturn at opposition on October 23
2°
Positions shown for the first of each month

OCTOBER

S	M	T	W	T	F	S
				1	2	3
4	○	6	7	8	9	10
11	◑	13	14	15	16	17
18	19	●	21	22	23	24
25	26	27	◐	29	30	31

Day Time (EDT, before October 25)

1 **8 a.m.**
The moon passes 3° north of Uranus

4 **5 a.m.**
The moon passes 0.2° south of Jupiter

6 **noon**
Mars passes 0.9° north of Regulus (morning)
9 p.m.
The moon passes 1.8° south of Saturn

9 **noon**
The moon passes 0.4° north of Aldebaran

15 **1 p.m.**
The moon passes 0.5° south of Regulus
midnight
The moon passes 1.0° south of Mars

21 **2 p.m.**
The moon passes 7° north of Mercury
Orionid meteor shower peaks

23 **3 p.m.**
Saturn is at opposition

27 **10 p.m.**
The moon passes 2° north of Neptune

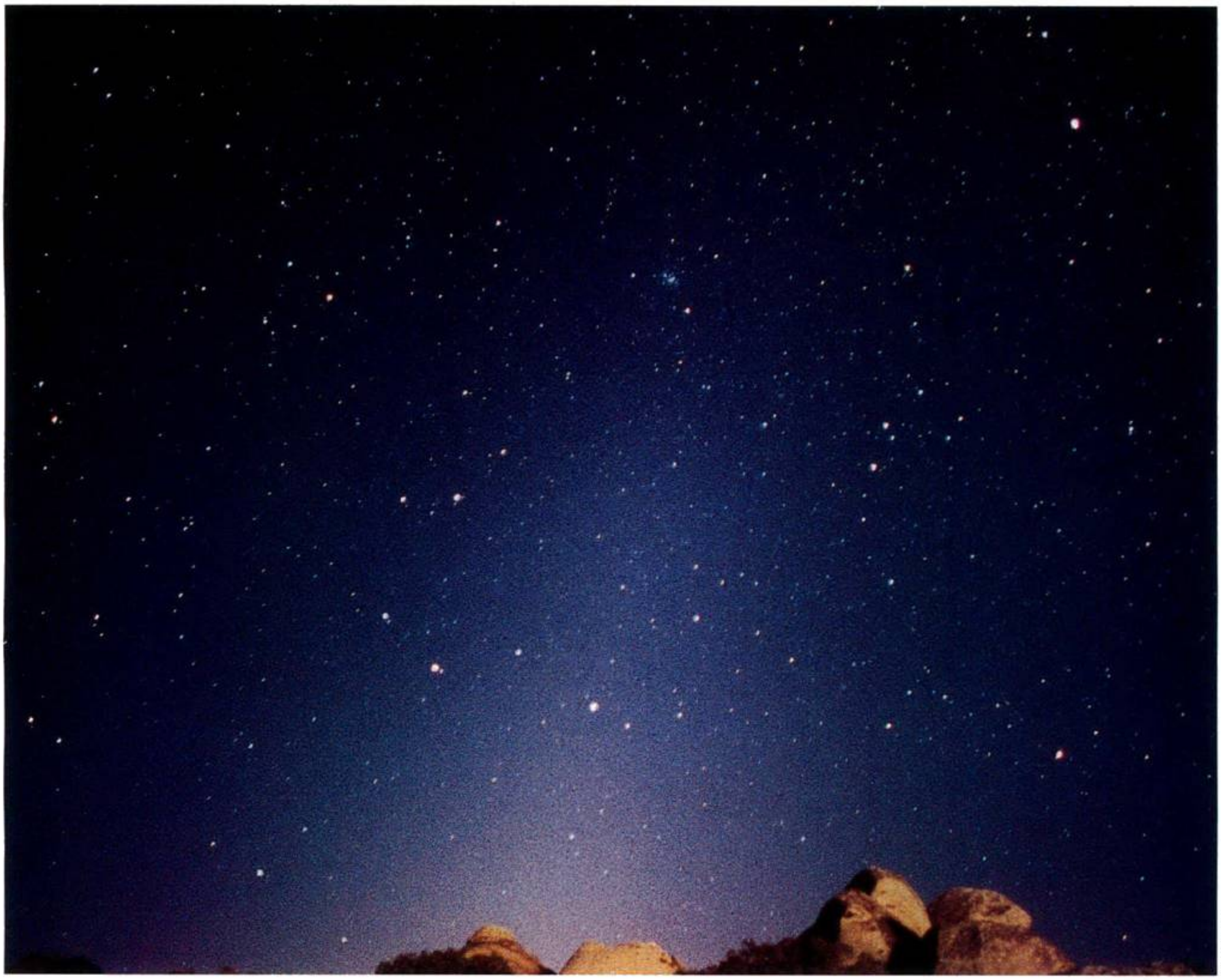
28 **3 p.m.**
The moon passes 2° north of Uranus

29 **11 p.m.**
Venus is in superior conjunction

31 **11 a.m.**
The moon passes 0.2° south of Jupiter

Two of the largest and most prominent rings, the A ring, discovered in 1675 by Giovanni Cassini, and the B ring, first gleaned by Galileo in 1610, are separated by a dark gap called the Cassini division. In 1979, planners originally targeted a spacecraft called Pioneer 11 to fly through this supposedly vacant gap. But scientific second thoughts told them not to be so reckless, and a safer trajectory closer to the planet was selected. It turns out the hunch was right; within a year, another spacecraft, Voyager 1, found the Cassini division was full of — you guessed it — still more ringlets invisible to earthbound telescopes.

Glimpse the False Dawn's Soft Glow



Jerry Schad

While Jupiter and Saturn blaze away on these long autumn nights, a much subtler light beckons early morning observers. About an hour or two before morning twilight commences, look toward the east for a huge, softly glowing pyramid of white light. Known as the zodiacal light, or "false dawn," this ethereal glow never fails to impress both novice and seasoned skygazers.

As its name implies, the zodiacal light is a glow found along the zodiac, the broad band of sky that encompasses the paths of the planets. From mid-northern latitudes, the zodiacal light is easiest to see on mornings in September and October because the zodiac then makes a steep angle to the eastern horizon. (For the same reason, it is relatively easy to see in the west after evening twilight during February and March.)

But the subtlety of the zodiacal light means you have to look for it under the right conditions. Observe from a dark location on a haze-free morning when the moon is out of the sky. And use your naked eye – binoculars or a telescope will render the zodiacal light invisible. At its brightest, the light is slightly brighter than the Milky Way.

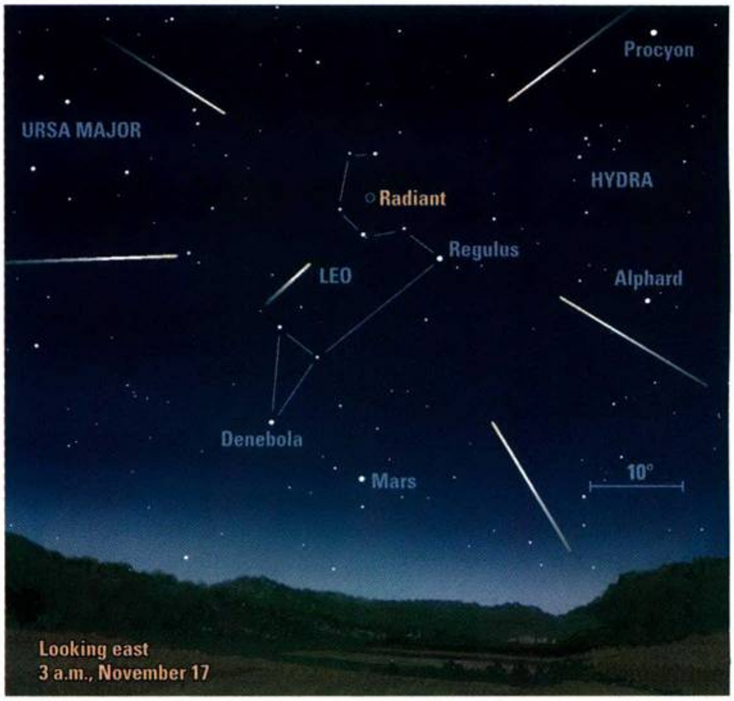
When you view the zodiacal light, you're seeing sunlight reflecting off small dust particles that lie in the plane of the solar system. Most of this dust comes from spent comets or the debris created by colliding asteroids.

NOVEMBER

S	M	T	W	T	F	S
1	2	3	○	5	6	7
8	9	◑	11	12	13	14
15	16	17	●	19	20	21
22	23	24	25	◐	27	28
29	30					

Day	Time (EST)
3	**4 a.m.** The moon passes 1.7° south of Saturn
5	**9 p.m.** **The moon passes 0.6° north of Aldebaran**
9	**4 a.m.** Mercury passes 1.9° north of Antares (evening)
11	**4 a.m.** Mercury is at greatest eastern elongation (23°, evening) **5 p.m.** The moon passes 0.3° south of Regulus
13	**1 p.m.** **The moon passes 0.5° north of Mars**
17	**Leonid meteor shower peaks**
20	**4 p.m.** The moon passes 7° north of Mercury
24	**4 a.m.** The moon passes 1.9° north of Neptune **10 p.m.** The moon passes 2° north of Uranus
27	**8 p.m.** **The moon passes 0.6° south of Jupiter**
28	**5 p.m.** **Ceres is at opposition**
30	**3 a.m.** Pluto is in conjunction with the sun **noon** The moon passes 1.8° south of Saturn

Will Leo's Swarm Storm?



Looking east
3 a.m., November 17

Comets are cosmic litterbugs, tossing tons of dust off into space along their orbits. Comet Hale-Bopp dumped an astonishing 100 tons of material each second. It won't surprise you, then, to learn that comets are the mother of all meteoroids. And a meteoroid becomes a blazing meteor when Earth, blithely moving along in an orbit around the sun, plows into it to make it burn up in our upper atmosphere with a flash of light. So it follows that reliable meteor showers such as the August Perseids and the October Orionids fall like clockwork when Earth passes through a region of space littered by their passing parent comets. We owe the Perseids to Comet Swift-Tuttle and the Orionids to Comet Halley. Now here comes Comet Temple-Tuttle to precipitate what could be the Great Leonid Storm of November 17, 1998.

Dirty comet Temple-Tuttle passes through the inner solar system once every 33 years. On February 27 it makes its closest approach to the sun in more than three decades. A plethora of dust that moves in concert with the comet has, at times, created storms of up to 200 meteors each second. In November 1966, the last time Temple-Tuttle and company passed near Earth's orbit, observers in western North America saw between 200,000 and 1 million meteors stream from the Sickle of Leo the Lion in just one hour. At a crucial moment, during the predawn hours of November 17, Earth plowed through Temple-Tuttle's 22,000-mile-thick debris field. One observer commented, "We instinctively sought to shield our upturned faces from imagined celestial debris."

So the big question is, what will the 1998 Leonid meteor shower be like? That partly depends on whether the effects of gravity in the solar system have either compacted or spread out the debris field, or modified its orbit to make the storm appear a little early or a little late. Then there's the question of when and where Earth cuts through the swarm. Current predictions hold that a storm could occur around November 17 at 2:43 p.m. EST, which would favor Asian observers. Or maybe the storm will hold off a year until 8:48 p.m. on November 17, 1999. These are the precise times when Earth crosses Temple-Tuttle's orbital plane. Or maybe both dates will fizzle.

Perhaps the greatest of the Leonid storms occurred in 1833. Subsequent showers at 33-year intervals have produced bursts of from 100 meteors an hour up to the unbelievable rates of the great storm in 1966. Will it "rain stars" in 1998 or 1999? Watch the skies. At the very least, you'll get a celestial spritzing out of it.

METEOR SHOWERS FOR 1998

Name	Peak date	Moon's phase	Prospects
Quadrantids	Jan. 3	Waxing crescent	Good
Lyrids	Apr. 22	Waning crescent	Good
Eta Aquarids	May 5	Waxing gibbous	Fair
Delta Aquarids	July 28	Waxing crescent	Good
Perseids	Aug. 12	Waning gibbous	Poor
Orionids	Oct. 21	New	Excellent
Leonids	Nov. 17	New	Excellent
Geminids	Dec. 13	Waning crescent	Good

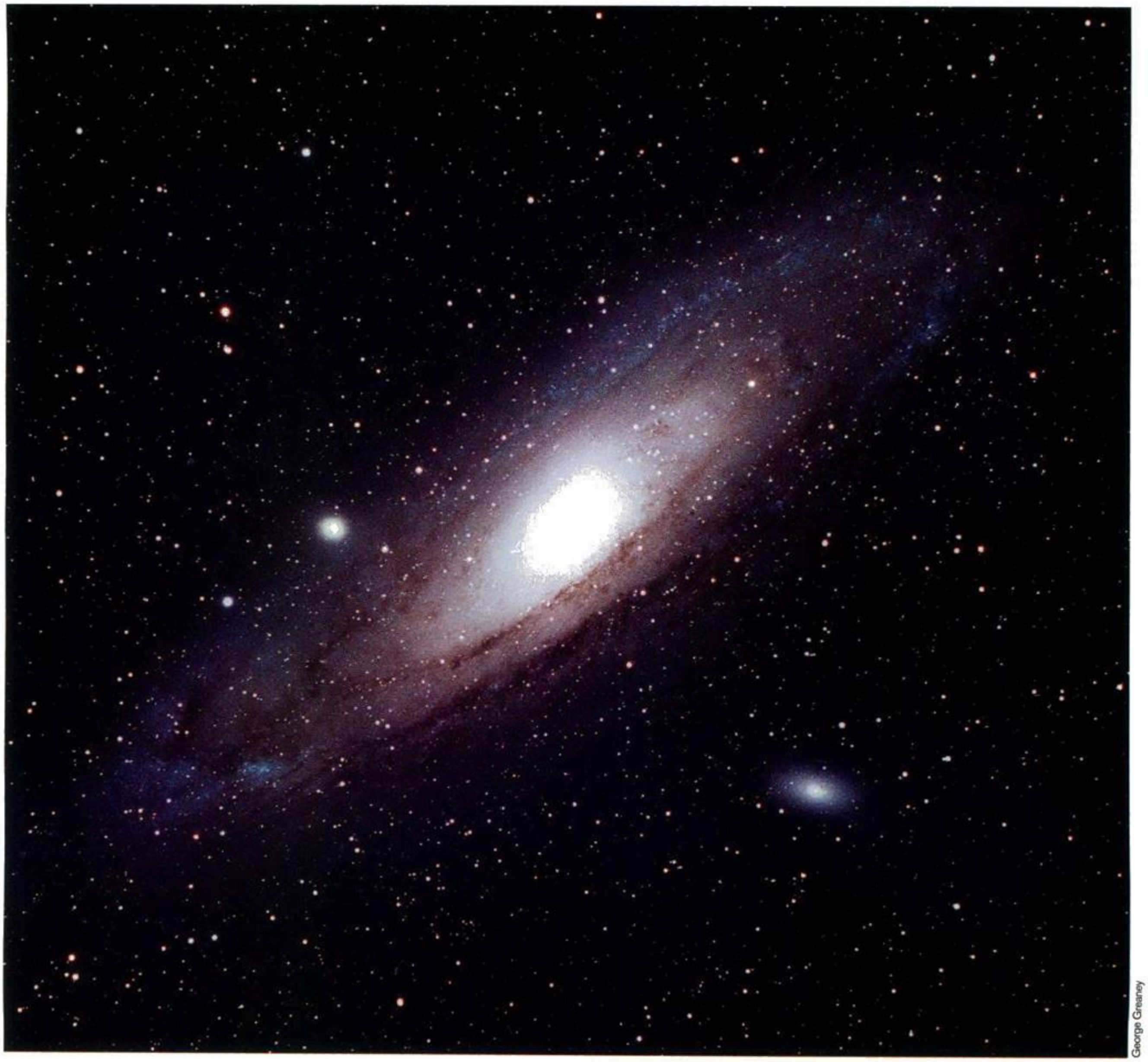
The Elusive Satellite Galaxies of Andromeda

Did you know that the Andromeda Galaxy (M31) has its own Magellanic clouds? The Magellanic clouds of our own Milky Way Galaxy look like fuzzy patches of light in the Southern Hemisphere's night sky. Early European explorers called them the "cape clouds" after the Cape of Good Hope. But after Ferdinand Magellan's circumnavigation of the world in 1519-1522, Magellan's historian Antonio Pigafetta renamed them in honor of the explorer. Today we know these patches are actually small, irregular satellite galaxies of the Milky Way.

Moving 2.4 million light-years from our home galaxy in the direction of the Andromeda Galaxy, we come to the elliptical galaxies M32 and NGC 205. They orbit their parent galaxy as satellite galaxies in the same way the Large and Small Magellanic clouds orbit our own Milky Way. Both can be seen quite easily in even the smallest backyard telescopes.

Look for M32 as a condensed, fuzzy "star" glowing at 8th magnitude just 24' to the south of M31's bright nucleus. Larger than M32 and appearing dimmer, NGC 205 lies just over a moon's width, 36', to the northwest of M31's core.

Like their Milky Way cousins, M31's satellite galaxies are tiny compared with their parent galaxy. Where M31 measures about 120,000 light-years across, NGC 205 and M32 measure 12,000 and 5,000 light-years in diameter, respectively. If you're an observer who likes a challenge, try finding two other satellite galaxies of M31, NGCs 185 and 147. They lie some 7° to the north of M31, over the border in Cassiopeia. A 6-inch scope should resolve the pair.



George Greaney

DECEMBER

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13	14	15	16	17	●	19
20	21	22	23	24	25	◐
27	28	29	30	31		

Day	Time (EST)
1	**10 a.m.** Mercury is in inferior conjunction
3	**8 a.m.** **The moon passes 0.6° north of Aldebaran**
9	**1 a.m.** **The moon passes 0.01° south of Regulus**
12	**3 a.m.** **The moon passes 1.8° north of Mars**
13	**Geminid meteor shower peaks**
16	**7 p.m.** The moon passes 3° north of Mercury
19	**11 p.m.** **Mercury is at greatest western elongation (22°, morning)**
21	**11 a.m.** The moon passes 1.7° north of Neptune **9 p.m.** Solstice (northern winter/southern summer begins)
22	**6 a.m.** The moon passes 1.8° north of Uranus
25	**6 a.m.** The moon passes 1.2° south of Jupiter
27	**6 p.m.** **The moon passes 2° south of Saturn**
30	**6 p.m.** **The moon passes 0.6° north of Aldebaran**

Meet Big, Red Mira

Step out under the stars tonight and you're likely to see a sky that's changed little in recorded history. Most of the constellations we know today come from ancient Greek, Arabic, or Roman legends thousands of years old. But the sky does change. Comets flash by, stars explode, and planets cruise along the zodiac. And, like fireflies on a summer night, some average stars wax and wane in brightness over a period of days or, in some cases, years. One of the first stars found to vary in brightness lingers low in the southwest after sunset this month, in Cetus the Whale. Mira the Wonderful is shining at its brightest in more than 300 days.

Stars like Mira are called long-period variable stars. They lazily expand and contract in size over several hundred days' time to range across several magnitudes in brightness. Mira's variability was first recognized in the 17th century, when astronomers realized that the star was visible at some times but not at others. They noted the star went through this cycle approximately every 331 days, although this period is far from constant.

Mira-type variables fluctuate in brightness as their size swells and then contracts. These red giant stars, slightly more massive than our sun, are reaching the end of their lives. For most of its life, a star chugs along by converting hydrogen fuel into helium and energy we sense as light and heat. The waste helium accumulates in a star's core until the hydrogen gets scarce. Then the star undergoes a metamorphosis to burn helium into carbon.

Chris Cook

A Cold (Meteor) Shower

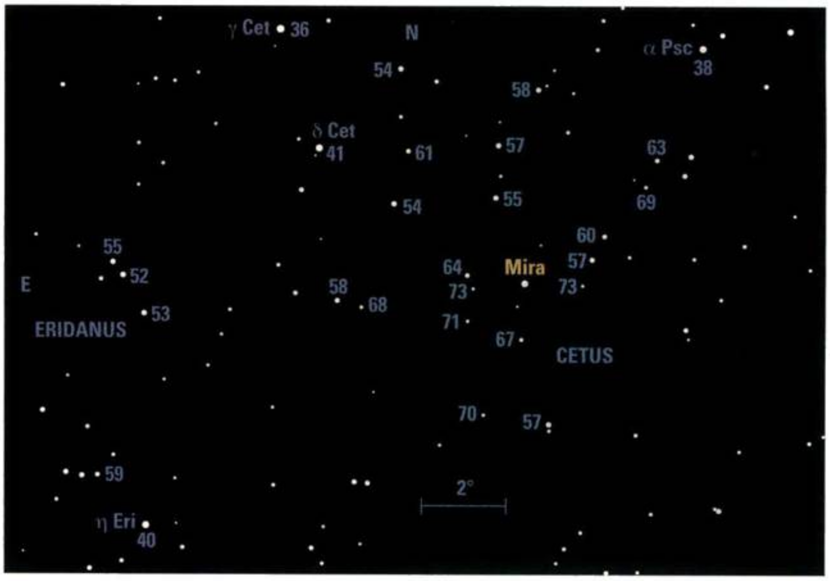
If it weren't so cold in December, you could bet that the Geminid meteor shower would surpass the August Perseids as everybody's favorite meteor shower. The Geminids, active from December 7 to 17, peak on the night of the 13/14th at up to 110 meteors per hour. Look for them to streak from the constellation Gemini. However, you'll see the most meteors by looking approximately 60° away from this radiant.

Most meteors start as meteoroids the size of a grain of sand floating through space. When Earth overtakes a Geminid meteoroid, it plunges into our upper atmosphere at more than 20 miles per second. Some of the bigger, rock-sized meteoroids, almost 1 in 20, are large and bright enough to leave a luminous, ionized train of gas along their line of travel. If a meteoroid survives the burning atmospheric entry (extremely rare for a shower meteor), it strikes the ground as a meteorite.

While most meteor showers can be traced to debris from an active comet, the Geminids have a more enigmatic source. Geminid meteoroids share the same orbit with an asteroid called 3200 Phaethon, which was discovered in the 1980s by the Infrared Astronomical Satellite. Are the Geminids fragments of a bona fide asteroid, or is Phaethon the core of a deceased comet that's long since stopped replenishing the meteor stream seen in Earth's skies? If the latter, Geminid numbers should taper off as the years pass.

At maximum size and brightness, Mira is some 400 times the diameter of the sun, or about 350 million miles across. If it replaced the sun in our solar system, its outer layers would engulf all the planets out to Mars. Despite its vast size, it contains only about two solar masses of material, meaning that most of Mira's bulk exists in a vacuum better than can be achieved in any laboratory on Earth!

Go out and see this rarefied star for yourself. It should reach a maximum brightness of about 3rd magnitude during December. It also reaches peak luminance earlier this year, in January. Mira's predicted time of maximum brightness has always been difficult to pin down; the period itself varies between 304 and 355 days. Use the comparison chart at right to figure when Mira shines at its brightest for the year, and enjoy one of the most striking subtleties our changing sky has to offer.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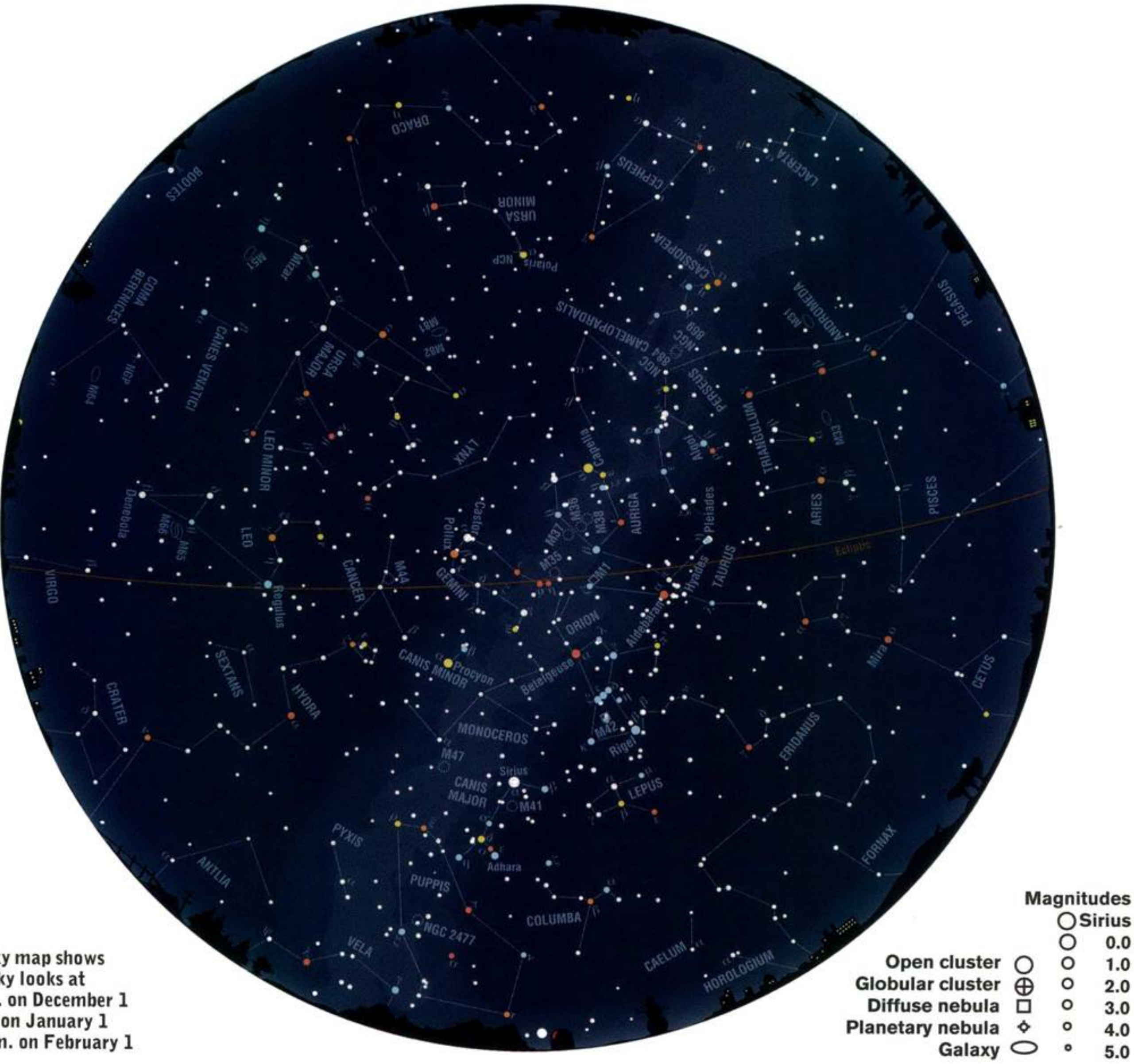
DRACO
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ORION
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Procyon
CANIS MINOR
SEXTANS
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CETUS
MONOCEROS
M42
Rigel
ERIDANUS
M47
CANIS MAJOR
Sirius
M41
LEPUS
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ANTLIA
Adhara
PUPPIS
FORNAX
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Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

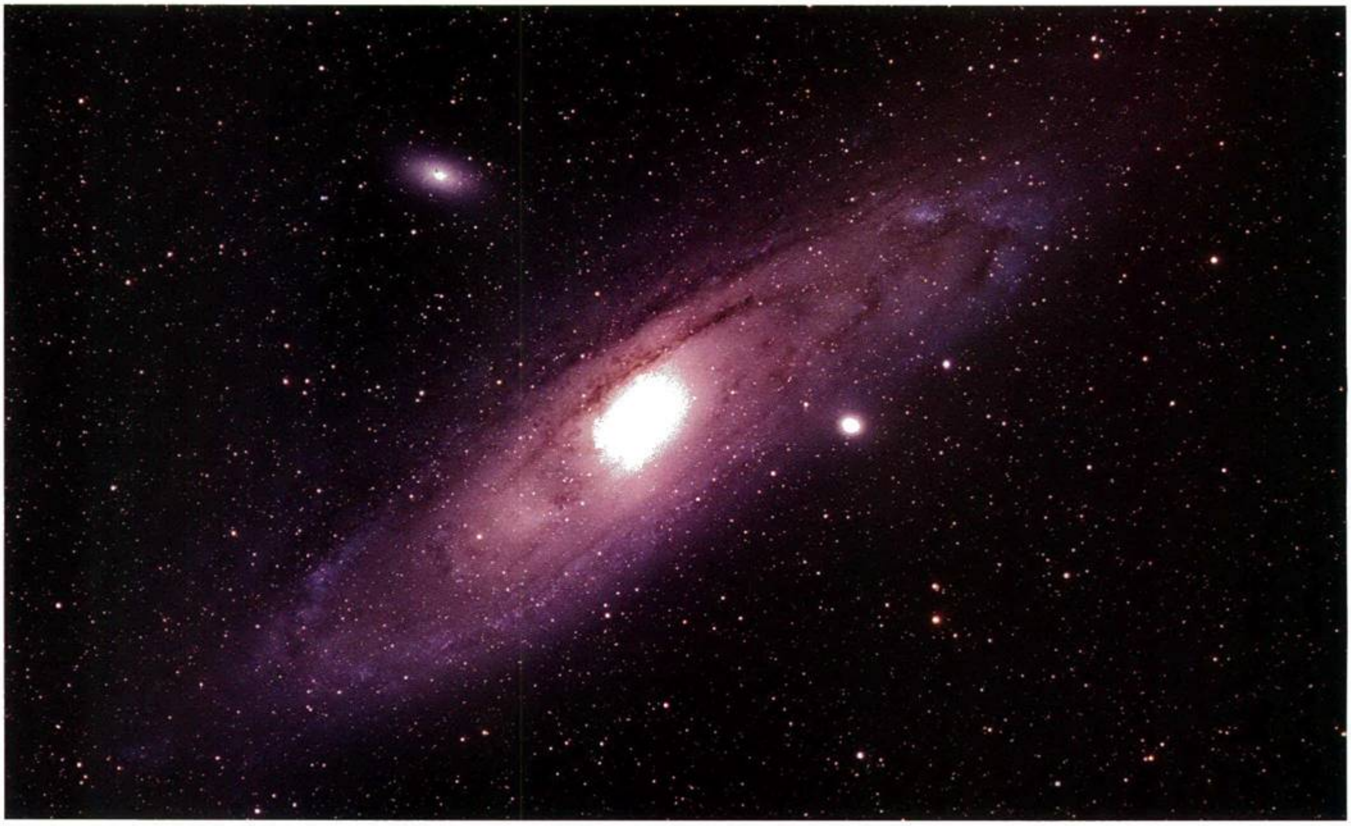
The all-sky map shows how the sky looks at
2:00 a.m. on December 1
midnight on January 1
10:00 p.m. on February 1

The Sky's
Greatest Showpieces

Take a guided tour of the brightest and best stars, galaxies, and clusters.

by Glenn F. Chaple, Jr.

The night sky is a gallery filled with cosmic masterpieces. It's one gallery open to the public every clear night of the year. There's no admission price; you need only your eyes, perhaps a pair of binoculars or a telescope, and a willingness to spend an hour or two outside on a clear moonless night. Framed by the inky blackness of space are double and multiple stars, star clusters, nebulae, and galaxies whose images evoke a sense of mystery and awe. In a lifetime, you could never hope to explore all of the heavenly works of art that even a modest sized telescope can unveil. But some stand out above all others. Join us as we pay homage to 25 of the heavens' great masterpieces.



The Andromeda Galaxy

GEORGE GREANEY

(6-inch f/7 refractor, hypered Fuji Super HG 400 film, composite of two 60-minute exposures)

The Andromeda Galaxy

(M31, NGC 224; 0h42.7m, 41°16' [2000.0], mag. 3.5, size 178' by 63')

On a clear moonless night, you can see M31 with the naked eye — a small patch of light near the star Nu (ν) Andromedae. Binoculars and small telescopes transform the patch into a bright oval with faint extensions that span 3° or 4°. Eighteenth and 19th-century astronomers thought M31 was a Great Nebula, a magnificent swirling gas cloud that would ultimately add a new solar system to our Milky Way Galaxy. Not until the early decades of this century was this nebula M31 resolved into stars, some of which were Cepheid variables. The Cepheids betrayed the enormous distance of this vast stellar swarm — more than two million light-years, well beyond the constraints of our galaxy. The Andromeda Nebula became the Andromeda Galaxy, and our universe has never been the same since.

Because the Andromeda Galaxy is so large and bright, it is an easy target for binoculars and small telescopes. High power isn't necessary. In fact, M31 is a grand sight in a 4- to 6-inch rich-field telescope coupled with an eyepiece that yields a magnification of 30 to 50x. Straddling M31 are two lesser misty glows. One appears as a fuzzy 9th-magnitude star, the other is a 10th-magnitude oval. These are the dwarf elliptical galaxies M32 and NGC 205, satellites of the gigantic spiral. Sometimes we are humbled when in the presence of a particular work of art. As we admire the images of the Andromeda Galaxy reproduced on these pages, we realize that we are looking at the accumulated light of several hundred billion stars. That light began its journey earthward 2.2 million years ago — one million years before the onset of the last Ice Age.

Here's something to contemplate as you look at the Andromeda Galaxy through your telescope. Residing within the glow may be millions of yellow dwarf stars like our sun, some which may be attended by earthlike planets. As you gaze at the Andromeda Galaxy, someone may well be gazing back.

Gamma Andromedae

(2h3.9m, 42°20', 2.3 + 5.1, sep. 9.8", p.a. 63°; Gamma And B, mags. 5.5 + 6.3, 0.4", 104°)

The sky teems with double, triple and multiple stars. Like the tiny paintings that crowd the walls of an art gallery, they are largely passed over by the casual visitor. But take the time to really look at one of these stellar partnerships, and you'll encounter a delicate beauty unmatched by the other types of deep-space masterpieces.

The Pleiades

GERALD RHEMANN

(6-inch refractor at f/9.8, hypered Fuji Super HG 400 film, composite of two 70-minute exposures)

The Double Cluster in Perseus

MARK E. KILLION

(5-inch refractor at f/5.9, Fuji Super G 400 film, 35-minute exposure)

Train your telescope on Gamma Andromedae. A magnification of 50 to 75x should suffice to reveal two stars. The colors are exquisite — topaz yellow for the main star and sapphire blue for its partner. These hues are also displayed by the more-celebrated Albireo in Cygnus, but Gamma's seem richer. Gamma Andromedae is a beautiful sight in even the smallest telescope, but there is a bonus for the owners of large-aperture telescopes. The secondary star, Gamma Andromedae B, is a close binary pair currently separated by a mere 0.4" (the apparent width of a penny five miles away). To split this duo, you'll need an optically sound 10-inch scope and an atmosphere steady enough to allow magnifications in excess of 300x. This beautiful system is about 260 light-years away.

Open Cluster M37 in Auriga

LEE C. COOMBS

(10-inch f/5 reflector, Ektachrome 400 film pushed to ISO 800, 15-minute exposure)

The Double Cluster

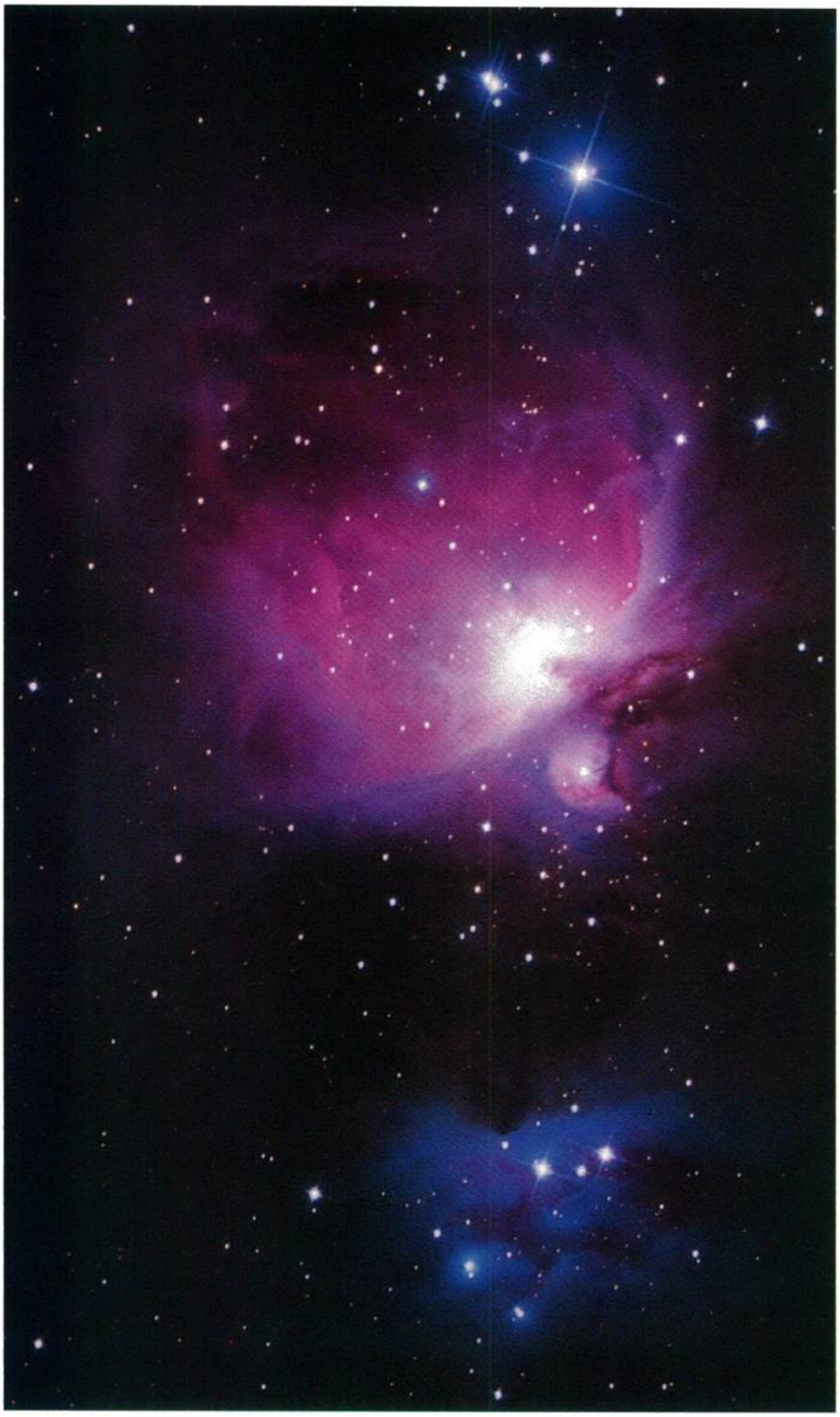
(NGC 869 and NGC 884; 2h20.7m, 57°08', 4.3 and 4.4, 30' and 30')

An open star cluster, its member stars sparkling like a distant swarm of fireflies, is one of the heavens' showiest works of art. Place two open clusters side-by-side, and you have a true masterpiece. Such is the visual feast presented by the Double Cluster in Perseus. Easily seen as a hazy glow midway between Perseus and Cassiopeia, the Double Cluster is a superb sight in small- to medium-sized telescopes.

Open Cluster M35 in Gemini

JERRY LODRIGUSS

(5.1-inch refractor at f/8, hypered Fuji 800 film, 45-minute exposure)



The Orion Nebula

MICHAEL STECKER

Because the two clusters are about one degree (two moon-widths) apart, you'll need low magnifying power to capture them together in the eyepiece field. Several hundred stars brighter than 12th magnitude inhabit both clusters. Each star is unbelievably luminous. Were our sun placed at the Double Cluster's estimated distance of 70,000 light-years, it would appear as a 16th-magnitude star.

The Pleiades

(M45; 3h47.0m, 24°7', mag. 1.2, size 110')

How many stargazers have looked up on a crisp winter night and been captivated by the sight of six or seven tiny glittering stars pressed close together in a dipper-shaped cluster? These are the Pleiades, or Seven Sisters. Easily the most beautiful naked-eye cluster in the sky, the Pleiades show their full splendor in binoculars and small wide-field telescopes. Dozens of Pleiades litter an area a little more than 1° across. Large-aperture instruments reveal fainter cluster members (the total exceeds 100), but fail to capture this large cluster in its entirety. Large scopes will, however, pick up the nebulosity that permeates this cluster, the last remaining vestiges of the great nebula that spawned the Pleiades millions of years ago. Photographs like the ones on this page show this nebulosity at its best.

Gazing at the Pleiades, you might become enchanted by the delicate beauty of these tiny sparks of light. But appearances can be misleading. If Alcyone, brightest of the Pleiades, were placed where our sun is, it would shine with an intensity equivalent to 1,000 suns and incinerate Earth in minutes. Fortunately Alcyone and her sister Pleiades are a safe 400 light-years away.

The Orion Nebula

(M42, NGC 1976; 5h35.4m, –5°27', 5.0, 66' by 60')

In every art gallery, there is a masterpiece whose indescribable beauty sets it apart from all the others. Our cosmic "Mona Lisa" is M42, the Orion Nebula. Its naked-eye appearance — a hazy glow in Orion's sword — reveals little of its grandeur. Under the scrutiny of even the smallest backyard telescope, the Orion Nebula becomes an object of wonder. Surrounding the star Theta^1 (θ^1) Orionis is a cloud of luminous gas spanning an area one degree across. Based on a calculated distance of 1,600 light-years, that one degree translates to an actual diameter of 30 light-years — a colossal cloud, indeed. Intricate detail shows dramatically in large scopes with magnifications between 100 and 200x. The Orion Nebula takes on an eerie greenish hue and is distinctly mottled. The chaotic appearance is appropriate for a place where starbirth is occuring. Slightly north of M42 is M43 — a detached part of the Orion Nebula that appears as a nebulous glow surrounding an 8th-magnitude star.

By itself, the Orion Nebula is one of the wonders of the universe. But there is more. Theta^1 Orionis is a beautiful multiple star. Four stars, of magnitudes

5.1, 6.7, 6.7, and 7.9, are arranged in a "Trapezium" that spans about 20" and is handily seen in a common 60mm refractor. Two other stars of 11th magnitude lie just outside the Trapezium and may be glimpsed with a 6-inch scope. This cosmic baseball diamond, whose light illuminates the great gas cloud that gave birth to it, is arguably the finest multiple star in the heavens. Even without the surrounding nebulosity, it would be a cosmic masterpiece. The Orion Nebula and its Trapezium form a celestial work of art that we eagerly revisit year after year.

Open Cluster M37

(NGC 2099; 5h52.4m, 32°33', 5.6, 24')

Auriga is home to a trio of grand open star clusters (M36, M37, and M38), all of which may be faintly glimpsed with binoculars and finderscopes. Each has a unique visual character, but M37 is generally regarded as the finest of the trio. Located roughly midway between Beta (β) Tauri and Theta (θ) Aurigae, M37 contains about 150 stars in an area less than one-half degree across.

In small scopes, M37 appears as a handful of faint sparkles immersed in a nebulous glow. Larger scopes completely resolve the cluster, which is located an estimated 4,500 light-years away. As long as we're in this wing of the gallery, we can also admire M36 and M38. M36 is smaller and sparser than M37, but is better resolved and more attractive in small scopes. M38 is comparable in size to M37, but contains fewer stars. Which of these masterpieces do you like best?

The Beehive Cluster

GEORGE GREANEY

(6-inch f/7.1 refractor, hypered Fuji Super HG 400 film, 30-minute exposure)

Open Cluster M35

(NGC 2168; 6h8.9m, 24°20', 5.1, 28')

Often, a masterpiece possesses an obvious outer beauty. Only when you gaze intently, do you discover a hidden surprise. At the foot of the twins, some 2½° northwest of Eta (η) Geminorum, lies the beautiful open cluster M35, one of the finest in the Messier Catalog. Similar in size and stellar population to M37, M35 is an especially beautiful sight in a 6-inch scope at 100x. And the surprise? Concentrate your gaze on an area about one-half degree from the southwest edge of M35. Can you see a faint glow? This is the 11th-magnitude open cluster NGC 2158 — a challenge for 3- to 4-inch scopes and resolved only by the largest amateur telescopes. One of the most remote open clusters, NGC 2158 is about 16,000 light-years away, six times the distance to M35.

Triple Star Beta (β) Monocerotis

(6h28.8m, –7°2', AB: 4.7 + 5.2, 7.3", 132°; AC: 4.7 + 6.1, 10.0", 124°; BC: 5.2 + 6.1, 2.8", 106°)

Without the telescope, we would never be able to appreciate the sky the way nature intended. To the unaided eye, Beta Monocerotis is an ordinary-looking 4th-magnitude star some 12° east of the Orion Nebula. Study this star with a good 3-inch telescope and a magnifying power of 100x, however, and one star becomes three. And what an incredibly beautiful triple star Beta Monocerotis is. The trio, located about 150 light-years away, is approximately equal in brightness (between 4.5 and 5.6 magnitude) and color (pure white) and is contained in an area a scant 10" across.

Galaxies M81 (bottom) and M82 in Ursa Major

RONALD E. ROYER

William Herschel dubbed Beta Mon "one of the most beautiful sights in the heavens." We concur.

Castor

(Alpha [α] Geminorum; 7h34.6m, 31°53'; AB: 2.0 + 2.9, 3.9", 70°; AC: 2.0 + 9.1v, 72.5"; 164°)

Some masterpieces have a historical significance. Alpha Geminorum (Castor) is a prime example. Two centuries ago, many astronomers believed that double stars were chance alignments of stars and had no physical connection. It was the redoubtable William Herschel who announced, in 1803, that Castor was a true binary star. Just one or two decades ago, Castor received little attention, its member stars a bit too close for resolution by the casual observer. But things have changed. The magnitude 2.0 and 2.9 stars are now nearly 4" apart — a bright and beautiful sight in a 60mm refractor at 100x. The orbital period of this binary is still sketchy, but seems to lie somewhere between four and five centuries.

About 72.5" to the south is a 9th-magnitude red dwarf that shares the proper motion of the main pair, making Castor a triple system. But Castor's multiplicity doesn't end there. Spectroscopic studies reveal that each of these three stars is a close binary. Castor is a sextuple star. As you gaze at this system, imagine the stately, perpetual waltz of these three stellar pairs 45 light-years away.

The Beehive Cluster

(M44, NGC 2632; 8h40.1m, 19°59', 3.1, 95')

Another masterpiece with its own history is M44, the Beehive or Praesepe

Edge-on Galaxy NGC 4565 in Coma Berenices

TONY AND DAPHNE HALLAS

Cluster. A naked-eye glow, midway between the twin stars Castor and Pollux in Gemini and the "Sickle" of Leo, it has captured the attention of skygazers since ancient times. Then, the Praesepe was regarded as a weather indicator. Its invisibility on an otherwise clear night was known to precede the arrival of clouds and rain. In 1610, the Preasepe was one of Galileo's first targets with the newly invented telescope, and he marvelled at the swarm of stars that greeted his eye. Their appearance, like a swarm of bees, led to the cluster's nickname, the Beehive.

The Beehive isn't as rich as some of its brethren Messier clusters, but it's big and bright and a spectacular low-power sight. About 50 stars fill an area 1½° across. One of the nearest open star clusters, the Beehive is 525 light-years away.

The Lagoon Nebula

TIMOTHY PRINTY

(10-inch SCT at f/6, Fuji 800 G film, 25-minute exposure)

Galaxies M81 and M82

(NGC 3031 and NGC 3034; 9h55.6m, 69°4', 6.9, 21' by 10'; 9h55.8m, 69°41', 8.4, 10' by 4')

When we explore the sky in search of galaxies, we usually concentrate on the great galaxy fields in Coma and Virgo. But galaxies that rank as cosmic masterpieces are often far removed from the Coma/Virgo region. Two examples, M81 and M82, make their home just a stone's throw from the Big Dipper. A line traced from Gamma Ursae Majoris through Alpha UMa and traced an equal distance beyond marks the approximate location of these galaxies, which may be faintly glimpsed in the finder on a dark night. The two may be viewed simultaneously in a low-power field, and there's an obvious contrast to their appearance. M81 is a smooth oval, while M82 is more spindly in shape.

A large telescope shows the classic spiral nature of M81. M82 retains its spindly appearance but becomes more mottled. The true nature of this galaxy is a mystery, but its nature as a powerful radio source indicated violent activity in the galaxy's core. Much closer than the Coma/Virgo galaxies, M81 and M82 are a mere 7 or 8 million light-years away.

Quasar 3C 273

(12h29m, 2°3', 12.8v)

Sometimes a work of art appears ordinary to all but the most educated viewer. Our "cerebral" masterpiece is 3C 273. Looking at 3C 273 through the telescope, the casual observer sees nothing but an ordinary 13th-magnitude star in a rather sparse region of Virgo. But this "star" is actually a quasar, the incredibly active nucleus of a galaxy one billion light-years from Earth. Quasars were discovered in the early 1960s when a group of "stars" that were strong sources of radio energy were found to have enormous red shifts. 3C 273 is the nearest and brightest quasar. It should be visible in a 6-inch scope, and under ideal conditions might be glimpsed in a 3-inch. When you look at 3C 273, the light hitting your retina has been traveling through space since Earth's Precambrian age. When it began its journey earthward, the land was essentially lifeless, and the most complex life forms on our planet were jellyfish and sponges. Knowing that, you can gaze at this tiny speck and see a true cosmic masterpiece.

Galaxy NGC 4565

(12h36.3m, 25°59', 10.5, 15' by 1.5')

The galaxies in our sky strike a seemingly infinite number of poses. Most notable are the spirals turned edge-in to our line of sight, their hubcap shaped images often bisected by a dark dust lane. Perhaps the finest example is NGC 4565 in Coma Berenices. Viewed with a small telescope, NGC 4565 is a fascinating sight — a ghostly tenth magnitude streak of light measuring 15' by 1.5'. You'll need an 8- to 10-inch telescope and dark skies to see the dust lane. This needlelike glow is one of the more captivating sights in the night sky. Although associated with the great Coma/Virgo galaxy cluster, NGC 4565 seems to be much closer (about 20 million light-years away), and is comparable in size to our Milky Way Galaxy.

Globular Cluster M3

(NGC 5272; 13h42.2m, 28°23', 6.4, 16')

Globular star clusters are arguably the most visually stunning inhabitants of the sky, especially when viewed with large-aperture telescopes. Just as galaxy afficionados set their sights on the galaxy rich Coma/Virgo region, skygazers who favor globular star clusters turn their attention to Sagittarius and

Ophiuchus. These constellations mark the center of our galaxy, around which an estimated 150 globular clusters orbit.

But a few globulars lie far removed from the galactic center. A notable example is M3, located about 40% of the way from Arcturus to Cor Caroli (Alpha Canum Venaticorum). In binoculars or small scopes, M3 is a circular 6th-magnitude blob of light. But turn a 6-inch or larger scope toward M3 and you see one of the sky's most magnificent sights — thousands of stars packed into a tight spherical mass, sparkling like a heap of sugar dropped onto a sheet of black velvet. Here is a masterpiece guaranteed to elicit a gasp of awe from even the most casual observer.

The Whirlpool Galaxy

(M51, NGC 5194–5; 13h29.9m, 47°14', 8.4, 11' by 8')

Another showpiece galaxy that lies apart from the Coma/Virgo cluster is M51, the Whirlpool Galaxy. You'll find M51 by sweeping with low power the region roughly one-third the way from Eta (η) Ursae Majoris (the end star in the Dipper's handle) to Cor Caroli. In small telescopes, M51 appears as a pair of luminous patches. The lesser smudge is NGC 5195, a galaxy that is gravitationally interacting with M51. M51 itself is a spiral, the first galaxy to reveal such structure. The "Whirlpool" was first noticed by the Earl of Rosse, who viewed M51 with a 6-foot reflector in 1845. Its whirlpool-like appearance is visible only in telescopes 8 inches or larger, with magnifications between 100x and 200x. The Whirlpool is 35 million light-years away.

Globular Cluster M3 in Canes Venatici

CLIVE GIBBONS

(8-inch SCT at f/8, Ektachrome 400 pushed to ISO 800, 55-minute exposure)

The Hercules Cluster

(M13, NGC 6205; 16h41.7m, 36°28', 5.7, 23')

M13 is a reason to invest in a large-aperture telescope. Like M3, this globular cluster is an easily-seen circular glow in binoculars and small-sized telescopes. (You can even spot it with the unaided eye about one-third of the way between Eta and Zeta Herculis in the "Keystone" of Hercules.) A 6-inch telescope or larger transforms M13 into a blazing star ball — richer even than M3. As many as one million stars reside in this great cluster, believed to be 160 light-years in diameter. No wonder most observers regard M13 as the finest globular cluster in the northern sky, and one of the greatest of all cosmic masterpieces.

What if the sun were one of M13's member stars? We can only imagine a sky littered with tens of thousands of stars shining brighter than 1st-magnitude — some blazing at full-moon brilliance. The nighttime sky would never be truly dark, and the universe beyond would remain virtually unseen. As it is, we must admire M13 from our vantage point 25,000 light-years away. Just one-half degree northeast of M13 is the 11th-magnitude galaxy NGC 6207. Overlooked because of its proximity to M13, it may be captured by a 3-inch scope on a clear evening.

The Wild Duck Cluster

LEE C. COOMBS

(10-inch f/5 reflector, Ektachrome 400 film pushed to ISO 800, 15-minute exposure)

The Lagoon Nebula

(M8, NGC 6523; 18h3.8m, –24°23', 5.0, 80' by 40')

Some masterpieces are prized for their rarity. A bright nebula like M8 (The Lagoon Nebula in Sagittarius) is an example. Visible to the naked eye as a faint smudge some 5° west of the star Lambda (λ) Sagittarii, M8 looms large in telescopes of all apertures. With a diameter in excess of one-half degree, the M8 is a stunning low-power sight. The nebula gets its nickname from the dark band (the "Lagoon") that bisects it. M8 actually appears as two separate nebulae in small scopes, the southernmost remnant containing the coarse open cluster NGC 6530, about 10' in diameter. Like the Orion Nebula, the Lagoon is a very complex object, and is a fascinating study for large-aperture telescopes and moderately high magnifications.

After visually feasting on M8, direct your attention 1½° to the north-northwest. There you'll find M20, the Trifid Nebula. The Trifid is fainter than the Lagoon, but is still well-seen in telescopes of any aperture. It, too, has a complex structure that results from the intertwining of both bright and dark nebulae. The Lagoon and Trifid nebulae lie more than 5,000 light-years away.

The Omega Nebula

(M17, NGC 6618; 18h20.8m, –16°11', 6.0, 45' by 35')

Ocassionally, a masterpiece takes on a variety of appearances, depending on who happens to be studying it. Such is the case with the bright nebula M17. Located 10° north and slightly east of M8, M17 is a unique telescopic sight. In small scopes, M17 presents a distinct checkmark appearance. Or does it look like a swan? Or the number 2? Larger scopes bring to light more of the fainter nebulosity, and we see the Greek letter omega. Whatever its visual persona, M17 is unforgettable.

The Whirlpool Galaxy

MICHAEL STECKER

The Omega Nebula

MICHAEL STECKER

Globular Cluster M22

(NGC 6656; 18h36.4m, –23°54', 5.9, 17')

Because of their enormous distances, globular clusters are all but impossible to resolve in small-aperture telescopes. Fortunately, we have an exception — the globular M22, located about 2½° east and slightly north of Lambda Sagittarii. M22 is one of the nearest globulars, its distance being half that of M13. Viewed with a 3-inch telescope magnifying 100x to 120x, M22 appears decidedly grainy. Resolution to the core can be accomplished with an 8-inch scope. Unlike many of its brethren globulars, M22 is somewhat elliptical in shape.

Many great masterpieces have a background shrouded in mystery. The mystery surrounding M22 is who discovered it. Since it bears a Messier designation, we might assume the initial sighting of this globular was made by the famed 18th-century comet hunter himself. But many of the 100+ objects contained in his catalog were discovered long before Messier's time. Most sources credit discovery of M22 to a German astronomer named Abraham Ihle in 1665. But did the Polish astronomer Johannes Hevelius see it prior to 1665? M22 is one of many cosmic masterpieces whose rightful discoverer may never be known.

The Double Double

(Epsilon [ε] Lyrae; 18h44.3m, 39°40'; Epsilon^{1,2}: 4.7 + 4.7, 207.7", 173°; Epsilon^{1}: 5.0 + 6.1, 2.6", 357°; Epsilon^{2}: 5,2 + 5.5, 2.3", 94°)

If double stars are your favorite form of cosmic artwork, you'll love Epsilon Lyrae, the double double. Located 2° east of the bright star Vega, Epsilon Lyrae is a naked-eye double — barely. These two stars are separated by 208", close to the theoretical limit of resolution for the human eye. If you can separate the two, your eyes have passed one of the heavens' sternest vision tests. The real visual treat happens when you examine Epsilon Lyrae with a telescope and a magnification of 100x or more. Each of these stars is a close double. What makes the two pairs so remarkable is their similarity in brightness and separation. Both are binaries with very long orbital periods. We guarantee that this cosmic masterpiece will double your viewing pleasure.

The Wild Duck Cluster

(M11, NGC 6705; 18h51.1m, –6°16', 5.8, 12')

Open star clusters are much sparser than the globulars. The typical open cluster contains several hundred stars, while a globular cluster will boast a stellar population in the thousands. One of the richest open clusters is M11, the "Wild Duck Cluster." Located 2° south and slightly east of Beta Scuti, M11 actually looks like a partially resolved globular cluster when viewed with small scopes. A 6-inch telescope magnifying 100x fully resolves the M11, revealing a swarm of bright cluster members said to resemble a flock of wild ducks. M11 contains an estimated 1,000 stars brighter than magnitude 17, and lies approximately 5,500 light years away.

The Ring Nebula

(M57, NGC 6720; 18h53.6m, 33°2', 9.0, 1.2' by 1')

Planetary nebulae are the final gifts that dying stars bequeath to the "Night Sky Gallery." The typical planetary nebula is created when the core of a star in its final stages of life collapses, ejecting the star's outer layers into space. The expanding shell of gases takes on a spherical shape not unlike a planetary disk. Some planetaries, like M57, the Ring Nebula in Lyra, rank among the finest of cosmic masterpieces. M57 is easily located about midway between Beta and Gamma Lyrae. Viewed through the eye of a small telescope, the Ring appears as a ghostly oval, 80" by 60" in size and equal in brightness to a 9th-magnitude star. A 6-inch or larger scope magnifying about 100x will capture the annular appearance of M57. The central star, with an estimated magnitude of 15, is a challenge for 12-inch scopes. Astronomers estimate the distance to the Ring Nebula at about 1,200 light-years; its true diameter must be a whopping half light-year.

The Dumbbell Nebula

(M27, NGC 6853; 19h59.6m, 22°43', 7.6, 8' by 5')

If you like 3-D art, M27, the Dumbbell Nebula, is one cosmic masterpiece you'll want to visit. M27 is the most conspicuous of all planetary nebulae, but it tends to hide in the star-rich Milky Way fields of Vulpecula. Binocular users may see the 7th-magnitude glow just one-half degree south of the star 14 Vulpeculae. In small telescopes, M27 appears rectangular. The "Dumbbell" or hourglass shape requires at least an 8-inch scope. This is also the smallest aperture that will capture the 13th-magnitude central star. M27 is about 950 light-years away and is a collossal 2½ light-years across.

The Hercules Cluster

JASON WARE

(16-inch SCT, Fuji G 800 film, 30-minute exposure)

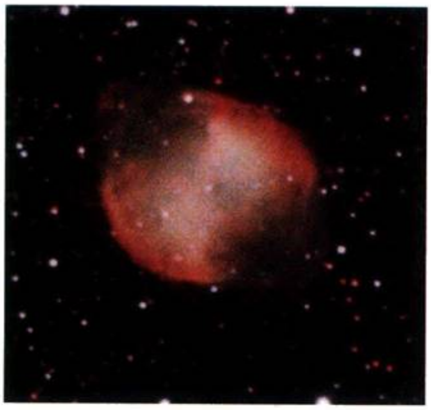
Some observers have noted a 3-D effect when viewing the Dumbbell. The nebula seems to hover in the foreground of the eyepiece field. As with any 3-D art, the effect won't be obvious to everyone. Give it a try.

The Saturn Nebula

(NGC 7009; 21h4.2m, –11°22', 8.4, 0.4' by 0.3')

Cosmic art purists may scowl that our previous two masterpieces are "planetary nebulae that don't look planetary." For their approval, we offer NGC 7009, the Saturn Nebula in Aquarius. Here is a classical planetary nebula in shape and size.

To find this beautiful object, scan the area two degrees west and slightly north of Nu Aquarii. Use medium power in your search; the Saturn Nebula looks starlike when viewed with low magnifications. When you encounter something that looks like an out-of-focus 8th-magnitude star with a distinct bluish tint, you've found the Saturn Nebula.



The Dumbbell Nebula

JACK NEWTON

(20-inch f/5 reflector, SRV 3200 film, cold camera, 18-minute exposure with a nebular filter)

Its dimensions make the Saturn Nebula a perfect match for its namesake planet. The "rings," or ansae, that extend out from the sides of the nebula can be glimpsed only through large telescopes. Don't be afraid to employ high magnifications on this object. The Saturn Nebula is what a planetary nebula is supposed to look like.

Herschel's Garnet Star

(Mu [μ] Cephei; 21h43.5m, 58°47', 3.5–5.0)

Our final cosmic masterpiece will make you see red — literally. It's the star Mu (μ) Cephei, also known as Herschel's "Garnet Star." Some stars, notably R Leporis and S Cephei, are even redder, but none is as bright or as easily found. To locate Mu Cephei with the unaided eye look south of a point midway between the stars Alpha and Zeta Cephei. Mu Cep's rich ruddy hue is best seen with binoculars and small telescopes. If you study this star over a period of several years, you'll notice that Mu Cephei fluctuates irregularly in brightness between magnitudes 3.5 and 5. It is an extremely luminous red supergiant with an estimated distance of 800 to 1,200 light-years.

Our tour of the sky is complete. Yet there are so many cosmic masterpieces we've failed to mention. Dazzling double stars like Mizar, Gamma Arietis, and Xi (ξ) Bootis. Splashy open clusters like M41 in Canis Major and NGC 7789 in Cassiopeia. Magnificent globular clusters like M5 in Serpens. Gossamer nebulae like the Veil and North America nebulae in Cygnus. And misty galaxies like M104 (the Sombrero) in Virgo and NGC 253 in Sculptor. If you're an astronomical newcomer, our 25 featured masterpieces make a great place to begin your exploration of the sky. Even veteran skygazers will want to revisit them time and time again. The ultimate trait of any great work of art, earthly or cosmic, is its timelessness. These cosmic masterpieces will continue to delight and awe viewers for centuries to come.

Globular Cluster M22 in Sagittarius

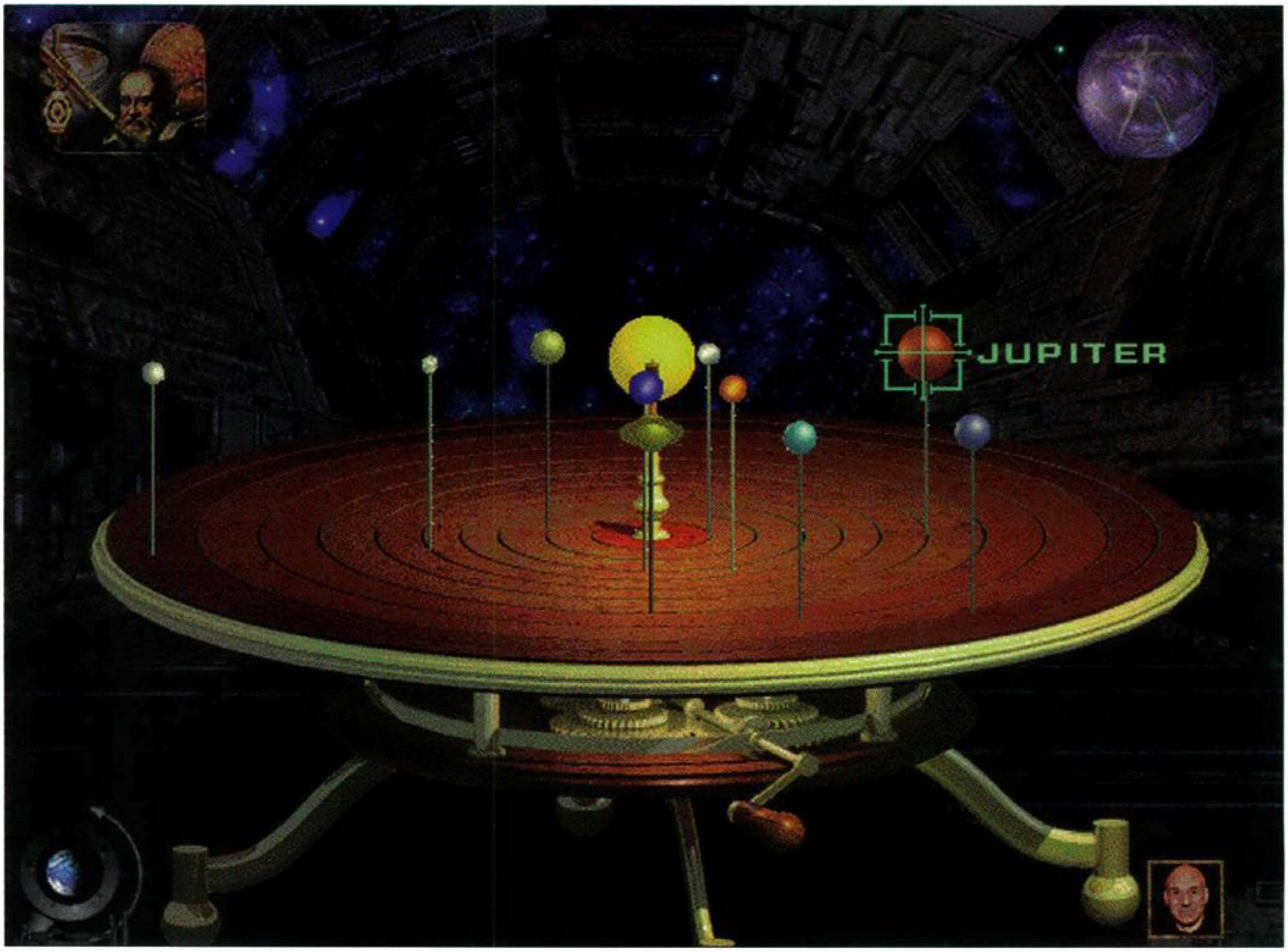
KIM ZUSSMAN

(11-inch f/10 SCT, 3M 1000 film, 26-minute exposure)

Navigating the
DIGITAL UNIVERSE

In a galaxy of astronomy software, choosing the right program can be a challenge.
Here are some of the best of the year.

by Kevin Gill and Tom Polakis



NINE WORLDS Looking for a terrific tour of the solar system? *Nine Worlds* has much to offer including an online launch to an exclusive website.

The personal computer is no longer "something to play with on a cloudy night." For amateur astronomers, it's become an invaluable tool, both in the field and at home. The increase in computer speed along with great leaps in memory and storage capabilities have made it a legitimate accessory. And, as many programs become Windows 95 compatible, sophistication and user-friendliness are unprecedented.

Additionally, because of the wide variety of software on the market, people of all ages and levels of expertise have access to the night sky like never before. Families have the universe at their fingertips in programs they'll use again and again.

Educational CD-ROMs have evolved into a useful resource. The ease of point-and-click technology makes learning fun for all ages. Beyond all the fun, however, CD-ROMs have interactive features that could not be available in any other medium.

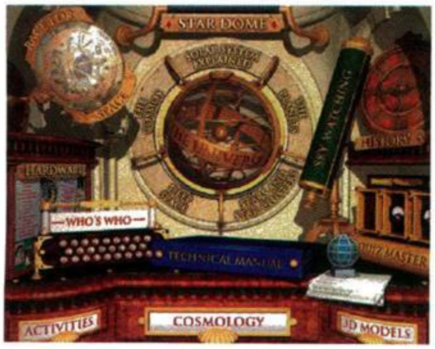
For more advanced amateurs, astronomical database software creates an entirely new way of planning observing sessions. Choosing the desired targets from a huge catalog lets observers make the most of those precious hours in the field under clear skies. Planetarium and charting software packages continue to reach higher levels of sophistication.

The release of the *Hubble Guide Star Catalog* and digitization of the *Palomar Sky Survey* have made planetarium and charting programs invaluable tools for field use. Here's a collection of our favorite pieces of astronomy software for education and real-time observing.

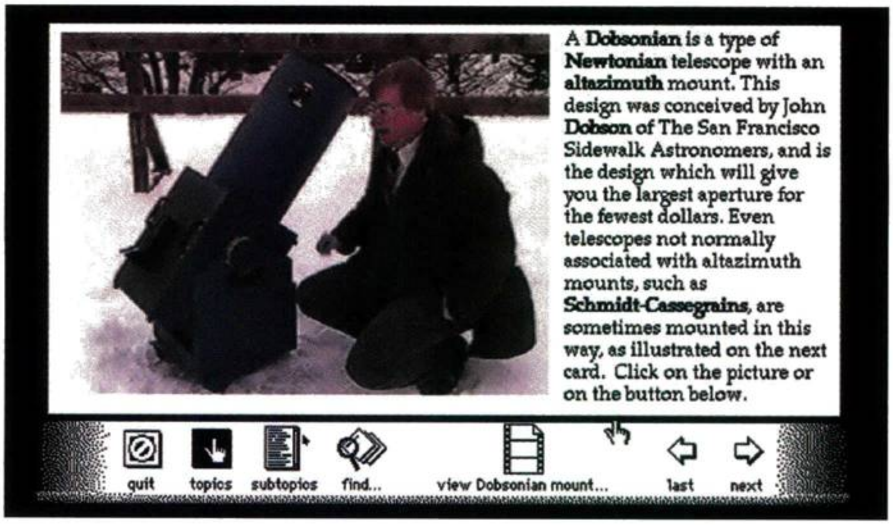
SOMETHING FOR EVERYONE

If you're interested in viewing a 3-D model of the Hubble Space Telescope or desire easily understood descriptions of deep-space objects, *Eyewitness Encyclopedia of Space and the Universe* (for Macintosh by DK Multimedia) might fill your need. From an attractive starting screen, you launch to such topics as "The Race For Space," "Who's Who," or "The Quiz Master." QuickTime movies with narration provide clear illustrations of complicated concepts including the gravitational slingshot of the Voyager spacecraft.

Nine Worlds (for Windows or Macintosh by Palladium Interactive) presents a terrific tour of the solar system, intuitively launched by pointing at your favorite planet and exploring from there. By narrowing its focus to the solar system, *Nine Worlds* can offer content more complete than the broad overviews found on many CDs. By dragging the cursor over a cutaway of a planet, you view its vital statistics. "History of Astronomy" presents a scrolling timeline from "The Ancients" through "Today and Tomorrow." Clicking on any of these, one can learn about mankind's perception of the universe during that time frame, as well as the prominent astronomers who promoted those views. Most impressive is the ambitious "Resource Explorer," which lists a countless number of items such as organizations, shareware, and points of interest. The "Online Launch" feature brings those with Internet access to the *Nine Worlds* website on the World Wide Web.



EYEWITNESS With Eyewitness Encyclopedia of Space and the Universe, you can take a trip to the moon, explore a galaxy, or watch a shuttle launch without ever leaving your desktop.



A **Dobsonian** is a type of **Newtonian** telescope with an **altazimuth** mount. This design was conceived by John **Dobson** of The San Francisco Sidewalk Astronomers, and is the design which will give you the largest aperture for the fewest dollars. Even telescopes not normally associated with altazimuth mounts, such as **Schmidt-Cassegrains**, are sometimes mounted in this way, as illustrated on the next card. Click on the picture or on the button below.

FUNDAMENTAL ASTRONOMY *Fundamental Astronomy* offers big bang for the buck. This program, produced by Mt. Allison University, provides answers to astronomy questions you never knew you had.

We round out our picks of favorite educational software packages with the impressive *Fundamental Astronomy* (for Macintosh by Mt. Allison University). Less flashy than most CDs, it focuses instead on packing as much information as possible into one disc. Clear movies and illustrations explain concepts such as precession, parallax, and planetary motions. The search engine and glossary ensure that you'll be getting your questions answered within a few minutes of inserting the disk. The sheer volume of pictures, movies, and clear, accurate descriptions and definitions makes this package a great buy. It's more advanced than the two software packages mentioned earlier, perhaps making it appropriate for high school and introductory college levels.

HANDS-ON TOOLS

Data for over 13,000 deep-sky objects and current information about solar system objects may be found in *DeepSky 2000* (for Windows by Steven S. Tuma – additional features are now available in a program called *DeepSky 97*). Not only can one filter a list of objects for viewing during a night's session, this software also has a logbook feature in which the previous night's observations may be entered.

NGC View (for Windows by Rainman Software) takes the database front end a few steps further. Along with a detailed data screen is a simple planetarium display that includes Telrad© circles and a graph depicting your target object's and moon's altitude and phase for a 24-hour period. Objects can be filtered and exported to a separate observing list linked to an observing log.

Make no mistake; this is a hands-on observing tool for the field. Features include the ability to develop object lists based on location, observing time, and altitude above the horizon. A new feature exports observing lists to *TheSky* (a planetarium program by Software Bisque), which then displays only objects contained in these lists, if desired. As its name suggests, data contained in *NGC View* is limited to the *New General Catalogue (NGC)* and *Index Catalogue (IC)*. Subsets of these, such as the "Herschel 400" or "Saguaro Astronomy Club's Best of the NGC" are broken out, but future additions of more catalogs would be a big plus for this program.

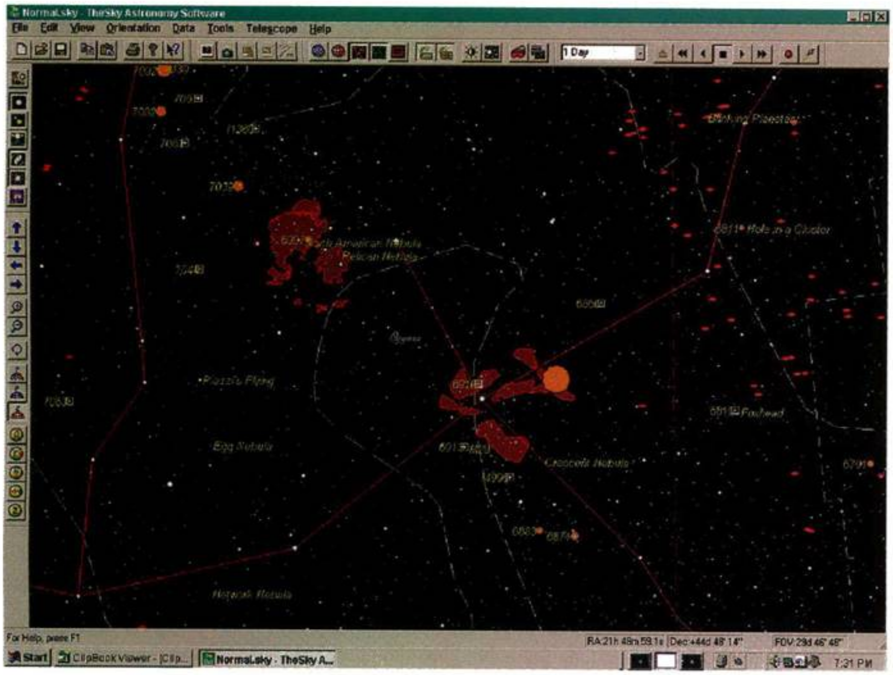
dObjects (for Windows by dObjects) has become our favorite data mine. Rarely does a piece of software tap into such a wide variety of the latest technology. This feature-rich database manager goes well beyond the standard. Among the 34,000-object database are targets from *Arp's Atlas of Peculiar Galaxies*, the *Third Reference Catalogue of Bright Galaxies*, and the RASC's "Deep-Sky Challenge Object" list.

The object information contained in these databases is only the beginning. Extensive references for each object are provided, including articles and photographs in various publications such as *Astronomy*, the Webb Society publications, and *Deep Sky*. Additionally, the

SELECTED CD-ROMS

Images	Distributed by	Price	Format	Description
Amazing Universe III	Hopkins Technology	$39.95	PC (Win 3.1)	500 images of planets and deep-sky objects
Apollo 17 Collection	Astronomical Research Network	$250	ARN, BMP	2 CD-ROMs full of images from the lunar mission
Comet Halley, Int'l. Halley Watch Vol 1-26	National Space Science Data Center	$260	FITS, PDS and text	Halley Watch data on 26 disks
Comet Smash	Network Cybernetics	$39	FITS, GIF, TIFF	700 images of Shoemaker-Levy 9 impact on Jupiter
Cosmic Background Explorer	National Space Science Data Center	$43		Data from DMR experiment on 1 disk
Cosmic Background Explorer	National Space Science Data Center	$20		Data from DIRBE experiment on 2 disks
Einstein Observatory	National Space Science Data Center	Call	FITS	High resolution images on 2 disks
Galileo Cruise Imaging	National Space Science Data Center	$84	PDS and VICAR	Images from Galileo on 14 disks
HST Archive	Digital Entertainment	$19.99	Mac/PC	Hubble Space Telescope images
Hubble Electronic Library of Picturebooks	Astronomical Society of the Pacific	$39.95	Mac/PC	Electronic Picture Books with hundreds of images
IRAS Sky Survey Atlas (ISSA)	National Space Science Data Center	$66	FITS	12.5° x 12.5° images on 11 disks
Invisible Universe	The Voyager Company	$39.95	Mac/PC	Tour the cosmos with astrophysicist Fiorella Terenzi
Journey to the Planets	Multicom Publishing	$59.95	Mac/PC	Fly-bys and images of planets
Jupiter Impact	Pacific HiTech	$29.95	GIF, BMP, PICT	Comet Shoemaker-Levy 9 impact on Jupiter
Magellan Venus data	National Space Science Data Center	$450		Radar mosaic images (FMAP) on 45 disks
Magellan Venus data	National Space Science Data Center	$1260		Radar mosaic images (F-MIDR) on 126 disks
Mars and Venus CD	Nick Marella	$29.95	BMP	600 Viking and Magellan images
Mars Digital Image Map	National Space Science Data Center	$1404	MDIM and GIF	Images of Mars on 14 disks
Mars: The Search Begins	WeMake CDs	$30	Win	Movies — Viking missions, first to land on Mars
Mission to the Moon	National Space Science Data Center	$880	PDS	Images of moon by Clementine on 88 disks
Multimedia Space Explorer	Betacorp	—	PC (Win)	Images and movies from space shuttle, Hubble, more
New View of Space	WeMake CDs	$30	Win	Movies — Various missions, from launch pad into space
RealSky CD	Astronomical Society of the Pacific	$250	Mac/PC	Palomar Obs. Sky Survey on eight CD-ROMs
ROSAT: The Images Vol. I-V, Version 1.0	National Space Science Data Center	$90		X-ray images from the Roentgen Satellite on 6 disks
Shuttle Encyclopedia	Walnut Creek CDROM	$39.95	GIF, text	3,000 images taken of and from space shuttles
Space	Seattle Support Group	$49.95	BMP, JPEG, PICT	200 images of planets and space
Space and Astronomy	Walnut Creek CDROM	$39.95	GIF, text	1,000 images of Earth, the planets, and space shuttles
Space View	Pacific HiTech	$29.95	—	500 images of planets with multilingual descriptions
Starlite	Astronomical Research Network	$49.95	ARN	1,000 images of planets, galaxies, and more
Stars and Beyond: Images of NASA	WeMake CDs	$30	BMP, GIF, PCX	375 images of the planets
Ultimate CCD Collection	Jack Newton and Don Parker	$29.95	Mac/PC	300+ of Newton and Parker's finest color CCD images.
Viking Orbiter images of Mars Vol. 1-32, 51-64	National Space Science Data Center	$460	PDS	Images on 46 disks
Visions of Saturn	WeMake CDs	$30	GIF	Voyager images of the Ringed Planet
Voyage to the Planets	Astronomical Research Network	—	ARN	Set of 7 disks of the moon and planets
Voyage to the Stars	Astronomical Research Network	—	ARN	Set of 5 disks of galaxies and nebulae
Voyager Moons	Nick Marella	$29.95	BMP	600 Voyager images of outer planets and their moons
Voyager Spacecraft to Uranus	National Space Science Data Center	$30	PDS	6,538 images on 3 disks
Voyager Spacecraft to Saturn	National Space Science Data Center	$50	PDS	4,000 images on 2 disks
Voyager Spacecraft to Jupiter	National Space Science Data Center	$160	PDS	6,000 images on 15 disks
Voyager Spacecraft to Neptune	National Space Science Data Center	$40	PDS	10,000 images on 4 disks
Welcome to the Planets Version 1.5	National Space Science Data Center	$10	GIF	190 images of planets, moons, comets, and spacecraft
Catalogs and databases				
Hubble Guide Star Catalog	Astronomical Society of the Pacific	$69.95	—	Positions and magnitudes of over 15 million stars
Principal Galaxy Catalogue	Observatorie de Lyon	$90	text	Information about 73,000 galaxies
Selected Astronomical Catalogs	National Space Science Data Center	$25	FITS and text	120 catalogs on 2 disks
Flares in Hydrogen Alpha	National Geophysical Data Center	$114	text	Solar flare records dating back as far as 1938
Regions of Solar Activity	National Geophysical Data Center	$114	text	Calcium plage and sunspot group data — 1958 to 1991
Interactive Disks				
A Brief History of Time	W.H. Freeman	$59.95	Mac/PC	Multimedia version of Stephen Hawking's book
Asimov's Library of the Universe	Zane Publishing	—	Mac/PC	Six-title collection explores the universe
Astronomical Explorations	E.M.M.E. Interactive	$27.99	Mac/PC	Guide to the solar system and beyond
Astronomy Village	NASA CORE	$5	Mac	Hands-on astronomy activities for 9th-grade students
Astroware	Network Cybernetics	$39	Mac/PC	Astronomy freeware and shareware programs
Explore the Planets	Tasa Graphic Arts	$59	Mac/PC	Comparative tour of planets and geologic processes
Eyes to the Stars	Wolf 359	$49.95	PC	Guidebook to astroimaging plus 600 images
Galaxy Guide	Parallax MultiMedia	$49.95	PC	Provides info on 38 constellations
Magic School Bus/Solar System	Microsoft	$49.95	PC	For children ages 6 -10
Night Sky Interactive	Beachware	$18.99	Mac/PC	Introduction to astronomy
Nine Worlds	Palladium Interactive	$39.95	Mac/PC	Voyage through the solar system
Space Rocks	Astronomical Research Network	$149.95	BMP	Images and information about meteorites
The Universe and The Planets	Byron Preiss	$39.95	Mac/PC	2 programs in one. *Scientific American's* deluxe CD-ROM.
Ultimate Einstein	Digital Bauhaus	$49.95	PC or Mac	Trace Einstein's life and scientific career
View from Earth	Warner New Media	$79.98	PC	Describes Earth, sun, and moon with text and images
Visions of Mars	Virtual Reality	$34.95	Mac/PC	Collection of literature and art about Mars
Voyage through the Solar System	Palo/Haklar	$49.95	Mac/PC	Describes all the planets using text, movies, and images

NOTE: Some prices reflect "street prices" available from mail order companies. Format indicates image file formats used or operating system needed to view the disks.



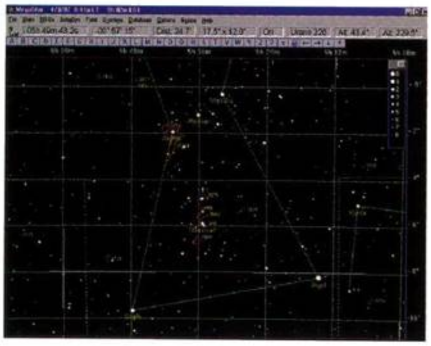
THE SKY A true 32-bit, Windows-based desktop planetarium, *TheSky* has many strengths, not the least of which is its ability to import databases, including the *Palomar Observatory Sky Survey (POSS)* with *RealSkyCD*. It can also provide fully remote observing by connecting to computer-controlled telescopes.

author has taken the reference section to the Internet, providing users with convenient links from the objects to associated web pages and ftp sites. *dObjects* even provides a direct interface to the source of online digitized Sky Survey plates. Rather than provide planetarium functions in the software itself, *dObjects* provides a direct interface to the popular planetarium programs that enables users to center the display on the object of interest.

Although complexity often increases with functionality, *dObjects* uses one of the most user-friendly interfaces we have experienced. Full balloon help is provided on almost all fields and displays, including abbreviations and observing logs. Complex queries become simple for the user without extensive knowledge of database structures and languages. Some features will be of limited use in the field, but from an Internet-connected site, extensive information about any object is at the user's fingertips.

LEARN THE SKY

Perhaps the most useful information an amateur astronomer can obtain from a computer is the appearance of the sky at any given place and time, and at any scale. *Megastar* (For Windows by E.L.B. Software) best fits the star charting requirements of even the most advanced observer. On launching the application, the user is presented with a comprehensive star chart and a self-explanatory set of menus. Pick your favorite star field, then zoom into it as deeply as 1.5' by 1.0', with stars from the *Hubble Guide Star Catalog* plotted to as faint as 16th magnitude. *Megastar* contains small touches that the observer will appreciate, such as a confirmation screen when coming out of night-vision mode, a star-magnitude scale that changes based on the field of view, and quick centering with a click of the right mouse button. It also scales cataloged galaxy sizes to reflect what is seen in small-aperture telescopes and



MEGASTAR The *Megastar* planetarium program is quickly becoming a favorite for Windows-based astronomers, both advanced and novice.

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Program Name	Version	Developer	Price	Comp	System	CD-ROM	H. Drive	Mem	Display	# Stars	# Objects	Opt DB
AstroSearch		Meade Instruments	$99.95	PC	Win		Y	640 KB	CGA	45,000 stars and objects		X
Big Blue Skies		Andromeda Soft.	S	PC	DOS				VGA	1,500		X
Dance of the Planets	2.71	ARC Sci. Sim.	$95	PC (386)	DOS 5		2MB	640KB	VGA	9,200	1,300	X
Dance of the Planets	Q.E.D.	ARC Sci. Sim.	$145	PC (386)	DOS 5		2MB	640KB	VGA	9,200	1,300	X
Deep Space	5	David Chandler	$129	PC (386)	DOS 5	X	14MB	2MB	VGA	15 million	20,000	
Deepsky 97		Steven Tuma	$25 and $45			opt.						
Distant Suns	2.0	Virtual Reality	$34.95	Mac	6 or 7	X	2MB	2MB	color	15 million	2,000	
Distant Suns-First Light	1.1	Virtual Reality	$64.95	PC (486)	Win 3.X	X	8MB	8MB	SVGA	15 million	2,000	
Earth Centered Universe	2.0B	Nova Astronomics	$50	PC (386)	Win 3.1 or Win95		7MB	4MB	VGA	245,000	10,500	X
Epoch 2000 sk		Meade	$149	PC	Win				EGA	259,000	13,000	
Epoch 2000 sk CD		Meade	$179	PC	Win	X			EGA	15 million	13,000	
Expert Astronomer		Expert Software	$14.95	PC	Win 3.X	X			VGA	9,100	2,000	
Guide	6.0	Project Pluto	$69	PC	DOS/Win	X	2MB	640KB	VGA	15 million	100,000	
Hipparchus	5.2.1	sofTouch APpL.	$49.95	Mac	6.X and 7.X			1MB		9,100	110	
HyperSky		Willmann-Bell	$49.95	PC	Win 3.1, Winn95	opt.	2.4MB	500KB	CGA	46,000	5,500	X
LodeStar	2.1	Zephyr Services	$89.95	PC	DOS				CGA	9,000	110	
LodeStar Plus II		Zephyr Services	$149.95	PC	DOS		N		CGA	9,100	7,840	X
LodeStar Pro	1.02	Zephyr Services	$259.95	PC (286)	DOS	opt.	3MB	2 MB	VGA	9,100	110	X
MacStronomy	2.0.3	Etlon Software	$60	Mac	6.0.4 or 7		2MB	2MB	color	10,000	1,100	X
MegaStar	3.1	E.L.B. Software	$129	PC (386)	Win 3.1 or Win95	X	5MB	4MB	VGA	15 million	110,000	
NGP	2.7	Gary Williams	F	PC	DOS		6MB	512KB	VGA		8,163	
NightSky		Zephyr Services	$59.95	PC	DOS				CGA	9,000		
NightSky		Zephyr Services	$79.95	PC	DOS				CGA	50,000		
Observer level I		Procyon Systems	$69.95	Mac	7			2.5MB		9,500	14,000	
Observer level II		Procyon Systems	$99.95	Mac	7		13.5MB	2.5MB		259,000	40,000	
Observer Deluxe	2.6	Procyon Systems	$199.95	Mac	7			2.5MB		259,000	40,000	
PC SKY	1.1	CapellaSoft	$99	PC (286)	DOS		3.2MB	640KB	VGA	178,000	200	
Personal Observatory		ISIS	$399	PC	DOS				VGA			
PLAstro		Zephyr Services	$99.95	PC	DOS		2.5MB		VGA	9,100		
NGCView for Windows	5	Rainman Software	$49.95	PC			5MB	8MB	VGA	250,000	13,266	X
Redshift	2	Maris Multimedia	$49.95	Mac/PC	7/Win	2X	1.5MB	8MB	color	250,000	40,000	
Remote Astronomy Software		Software Bisque	$299	PC	Win 3.X, Win95, and NT		Y		VGA			
Saguaro Database	6.0	Saguaro Astr. Club	$2								10,000	
Sky Chart	2.5	So. Stars Software		Mac	7		1MB	2MB	color	20,000	5,000	
SkyGazer - Guide to the Heavens		Carina Software	$40	Mac	6.0.5		3MB	1MB				
Sky Globe	3.6	KlassM Software	$20	PC	DOS		N	640KB	CGA	29,000	110	X
SkyLights		Zephyr Services	$89.95	PC	Win 3.1		Y			1,600	400	
Sky Pilot		Carina Software	$50	Mac	6.0.7					runs with Voyager II		
SkyTools	1.0	CapellaSoft	$119	PC (386)	Win 3.1	X	1MB	4MB	VGA	15 million	80,000	
Starry Night	1.03	Slenna Software	$37	Mac	7		3MB	4MB	color	65,000	10,000	
StarScape		Zephyr Services	$89.95	PC	Win 3.1		Y			9,000		
Stars & Scopes	3.4	So. Stars Software	$49	Mac	7		3MB	2MB	color	1,600	400	
StarTrax	1.01	Warme Software	$30	PC			750Kb	4MB	VGA	2,710	109	X
StarShow Viewer	1.04	Warme Software	$20	PC			500Kb	4MB	VGA	2,710	109	X
Superstar	4	picoScience	$149.95	PC	DOS		10MB	640KB	VGA	259,000	7,800	X
Superstar Pro	4	picoScience	$249.95	PC	DOS		10MB	640KB	VGA	259,000	7,800	X
The Cosmos	4.0	Mensys	$79	PC (386)	OS/2		5MB	1MB	VGA	259,000	10,400	X
TheSky level II	4	Software Bisque	$129	PC (386)	Win 3.X,	opt.	5MB	4MB	VGA	46,000	8,700	X
TheSky level III	4	Software Bisque	$199	PC (386)	Win 3.X, Win95 and NT	opt.	18MB	4MB	VGA	259,000	21,000	X
TheSky level IV (GSC)	4	Software Bisque	$249	PC (486)	Win 3.X, Win95 and NT	X	3MB	4MB	VGA	15 million	87,500	
Voyager II	2.0	Carina Software	$159.50	Mac	6.0.7	opt.	Y	1.5MB		259,000	12,000	X

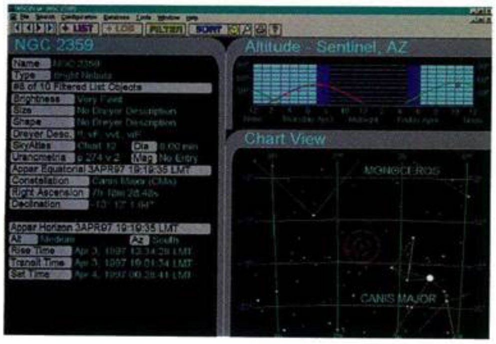
An "S" in the "Price" column indicates a shareware program; if you like the program and want to keep it, you pay the developer an amount specified in the program's documentation. An "F" indicates a freeware program; the developer provides this program to the community for free. The CD-ROM column lists "2X" when the software requires a double-speed or faster CD-ROM drive. "Display" lists the minimum requirement. The program may support higher video modes. "Opt. DB" indicates whether optional databases are available to extend either the stellar or deep-sky databases. Please call the developer for more information.

includes a no-nonsense status display that provides an object's corresponding *Uranametria* chart number. Astroimagers will find the database of over 13,000 asteroids useful. The routine for animating solar system objects is intuitive and quickly performed. And, only *Megastar* boasts the "Mitchell Anonymous Catalog," consisting of over 20,000 anonymous galaxies meticulously observed by Houston amateur Larry Mitchell.

On the down-side there are a variety of nuisances that can be attributed to the fact that this is not a full Windows application. Dialog boxes do not have the standard Windows look and feel, window positions are not remembered, and performance lags as screens are redrawn.

TheSky (for Windows by Software Bisque) is a true 32-bit, Windows-based planetarium program available for the PC. *TheSky* allows the user to configure the program to individual tastes, including control over tool- and status-bar options and the ability to define symbols and colors of deep-sky objects. In addition to basic charting of stellar, deep-sky, and solar system objects from a variety of included catalogs and those on the optional *DataPlus* CD, *TheSky* includes real-time horizon views, making it a true desktop planetarium. This allows the user to see the sky in its actual orientation from any site. Add to this a thoughtful free-rotation tool, and you can easily identify any star field you've observed or photographed. Some of its nice solar system utilities include the conjunction finder, eclipse finder, and jovian moon simulator.

What puts this software in a league of its own is its ability to logically import and export databases. With this option, you can import your favorite astronomical catalogs. Objects can then



Name [illegible]
Type [illegible]
#8 of 10 Filtered List Objects
Brightness Very Faint
Size No Dreyer Description
Shape No Dreyer Description
Dreyer Desc. [illegible]
SkyAtlas Chart 12 Dia [illegible]
Uranometria p 274 v 2 Mag No Entry
Appar Equatorial 3APR97 19:19:35 LMT
Constellation Canis Major (CMa)
Right Ascension [illegible]
Declination [illegible]
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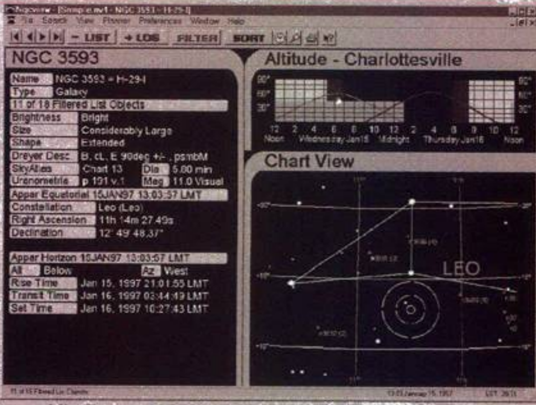

Name NGC 3593 = H-29-I
Type Galaxy
11 of 18 Filtered List Objects
Brightness Bright
Size Considerably Large
Shape Extended
Dreyer Desc B, cL, E 90deg +/- , psmbM
SkyAtlas Chart 13 Dia 5.80 min
Uranometria p 191 v.1 Mag 11.0 Visual
Appar Equatorial 15JAN97 13:03:57 LMT
Constellation Leo (Leo)
Right Ascension 11h 14m 27.49s
Declination 12° 49' 48.37"
Appar Horizon 15JAN97 13:03:57 LMT
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be filtered by size, brightness, or a variety of other characteristics to generate an observing list for an upcoming night. Couple this with a comprehensive set of data management tools, and any data set is available to the user.

Another big strenth of *TheSky* is its ability to connect to any of the popular digital setting circles or computer-controlled telescopes for fully integrated and remote observing sessions.

But, flexibility has its price. Some users may find the large list of options intimidating, especially adding new databases. Others may simply deem the effort unnecessary and not make full use them. However, if you enjoy customizing applications to your own liking, these features will allow you to create your personal astronomy program. Software Bisque is working on a Macintosh version for future release.

RealSkyCD (for Windows and Macintosh by the Space Telescope Science Institute and the Astronomical Society of the Pacific) is touted as the *Palomar Observatory Sky Survey (POSS)* at your fingertips. Compressed to occupy eight CD-ROMs, it is just that. When the Palomar set of photographic plates was taken in the 1950s, nobody could have dreamed that amateurs would have instant access on their personal computers in such a compact format. The *RealSky* set covers the sky down to a declination of –15°. Although the large amount of compression results in a rather blocky appearance for some objects, the utility of the *POSS* on your computer cannot be underestimated. For CCD imagers, this tool makes surveying asteroids and discovering new ones easier than ever before. *RealSkyView* (included) provides navigation and simple image-processing capabilities to smooth out those images, but you know the future has arrived when you run these CDs in conjunction with *TheSky*. From within *TheSky*, simply click on a toolbar button to create a Digitized Sky Survey image, and it appears, superimposed on your starchart. The deep penetration of the *POSS* will extend your star chart by several magnitudes, beyond the limits of even the *Hubble Guide Star Catalog*.

Voyager II (for the Macintosh by Carina Software) may be described as the most well-rounded of our software picks. It combines the features of both a planetarium and solar system simulation software. It not only enables you to make solar system animations from nearly any perspective imaginable, it also saves them as QuickTime movies. The sky may be viewed out to a 360° cylindrical projection for multi-year simulations. In addition to the excellent database of comet elements already supplied, earth satellite elements may be entered. Navigation is slick — it uses a pop-up menu of preset zooms and scrollbars that control position. A draggable analog clock controls time, which can be conveniently changed to sunrise, sunset, or astronomical twilight. A set of three twilight rings encircle the sun. Although at first glance this simple addition seems like a gimmick, it quickly becomes a useful feature indicating sky darkness by showing civil, nautical, and astronomical twilight times. *Voyager II* is the chosen software for celestial mechanics buffs. Carina Software will enter the Windows market with this software in the near future.

Whether you want to teach your kids something about astronomy, sort through giant databases, or make your own star charts, the personal computer can be a great assistant. Powerful machines can be had at reasonable prices — perhaps now is the time to use your computer to enhance your hobby. ■

Kevin Gill is a marketing consultant for the process control industry living in Cave Creek, Arizona. Tom Polakis is a deep-sky observer and photographer living in Tempe, Arizona.

THE WEBWEAVER PICKS

It seems the Internet is here to stay. Formerly synonymous with the term e-mail, it now sparks visions and conversations about the World Wide Web – the graphical interface to the Internet. Not only is it becoming a place to do business (because companies can show off their products to anyone in the world with an Internet connection and Web browser), but it has become a key player in providing any and all kinds of information – some of it accurate, some of it not. *Astronomy* is proud to present a website where you can find current and future stargazing information, meet *Astronomy*'s staff, find out about the latest meetings and star parties, get the latest press releases, and find the hottest links to other astronomy sources and businesses.

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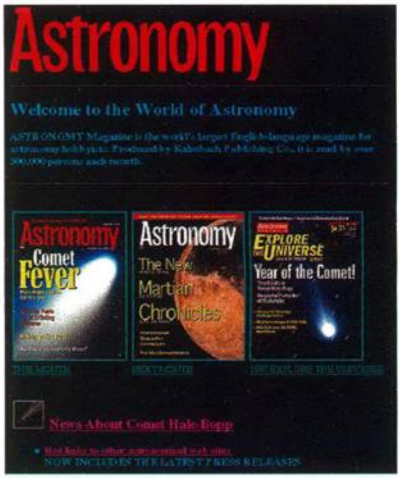

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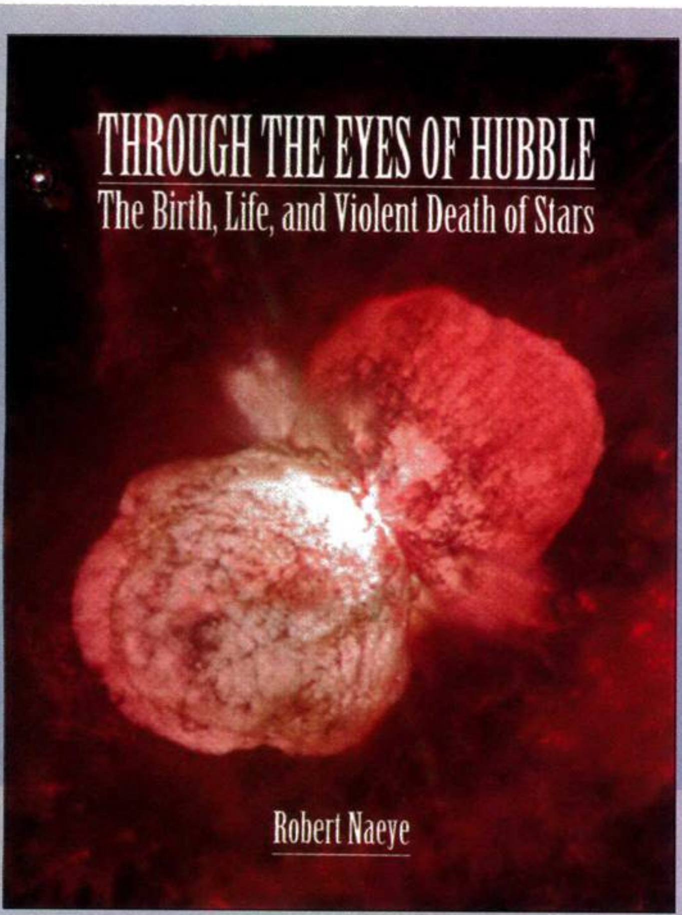
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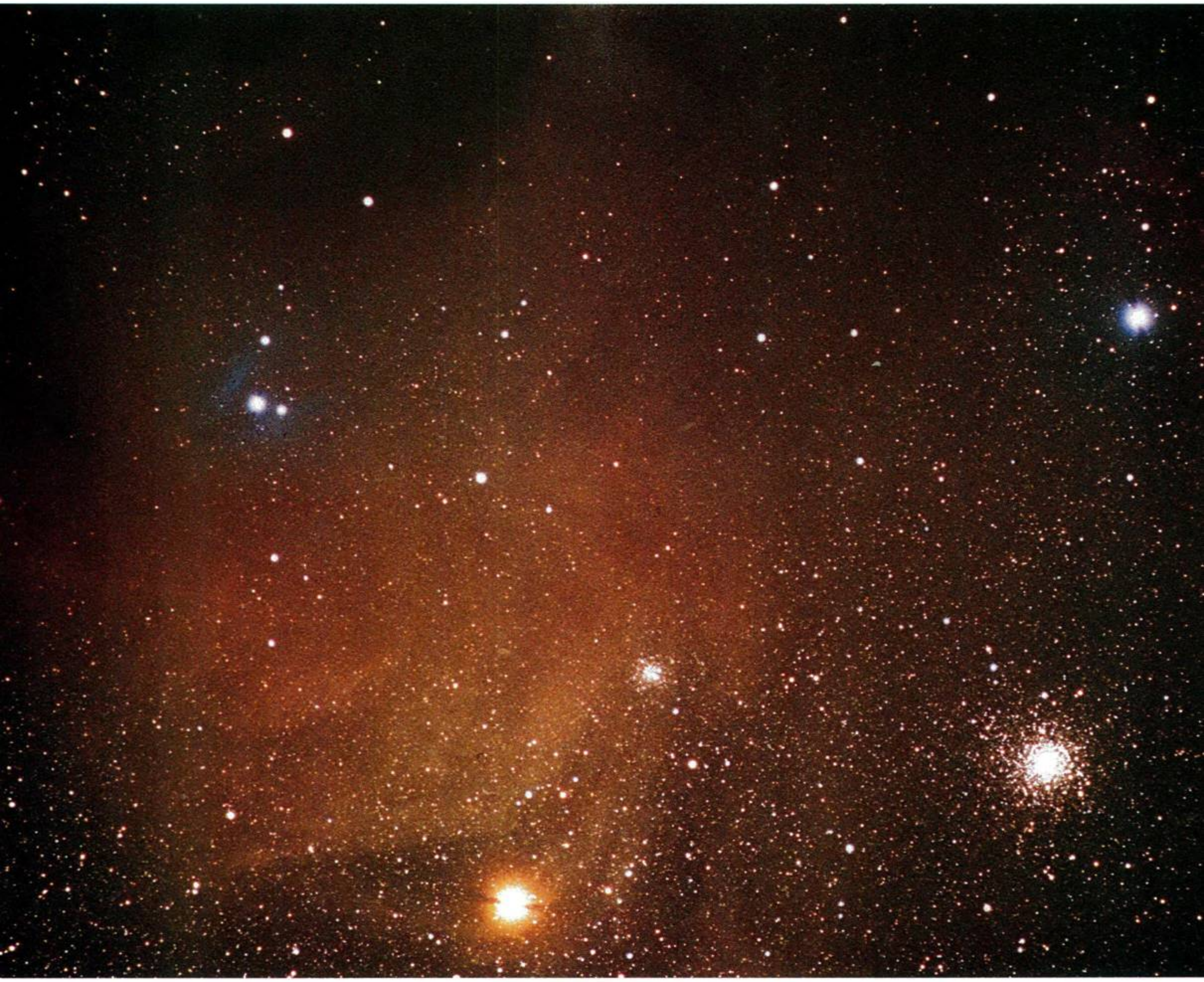
The Beautiful Universe

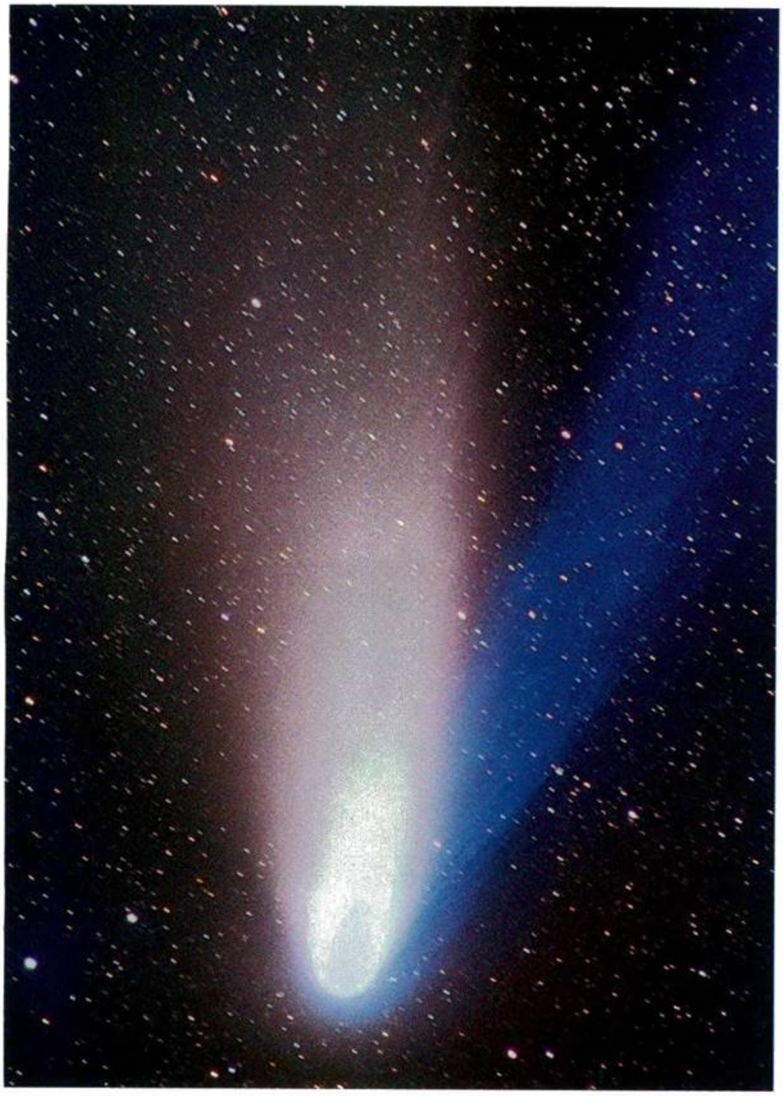
A gallery of the year's best photographs from the readers of Astronomy.



The Antares Region in Scorpius
Antares lies at bottom center, the blazing globular cluster M4 near bottom right, and the diminutive globular cluster NGC 6144 below center; the whole area is blanketed in the nebula IC 4606

VINCE AND MAGGIE FARNSWORTH

(4-inch f/5 refractor, Fuji Super G 800 film, composite of three 40-minute exposures)

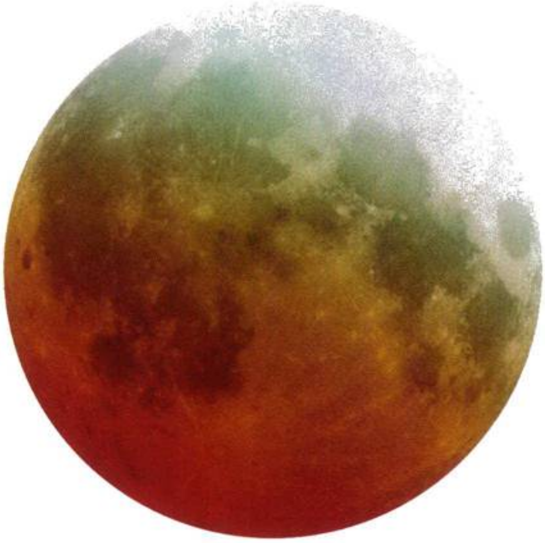


Comet Hale-Bopp Approaches Peak Brightness

The comet's blue ion tail and yellow dust tail appeared distinctly separated

MICHAEL STECKER

(5-inch f/4.5 refractor, Fuji Super G 800 film, 15-minute exposure taken March 15, 1997)

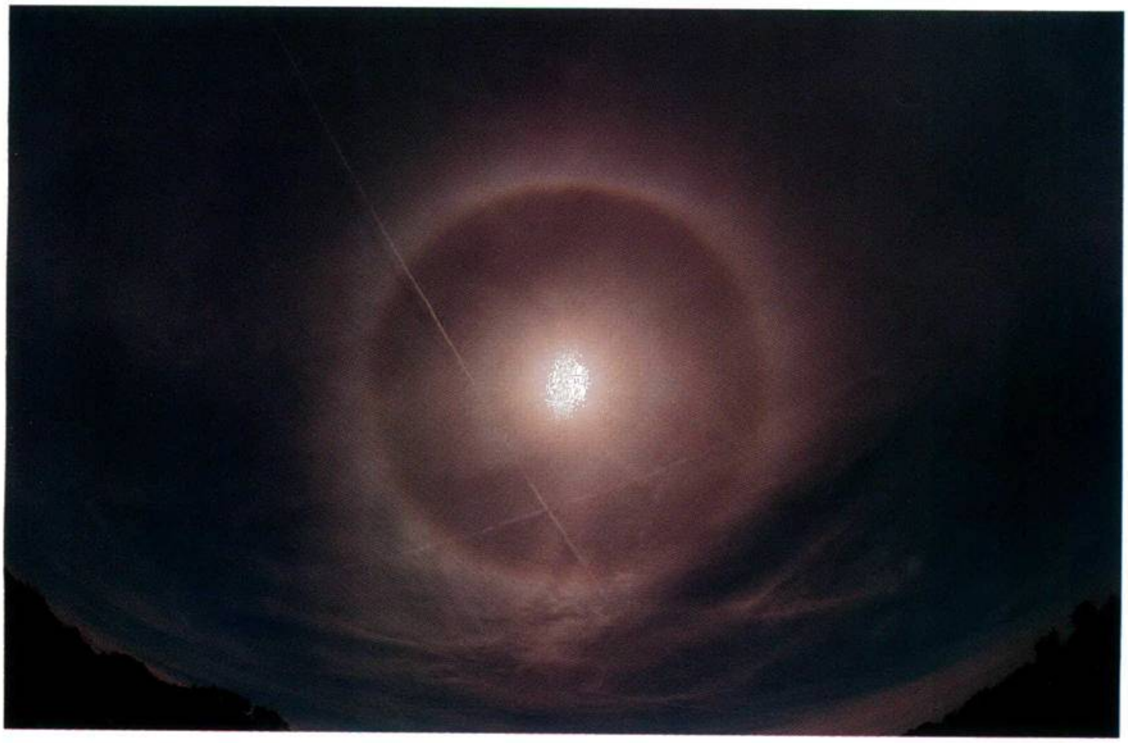


The Lunar Eclipse of March 23, 1997

The moon faded out during the prime observing window for Comet Hale-Bopp

GREGORY TERRANCE

(10-inch f/7 reflector, Fuji Super 800+ film, 5-second exposure)

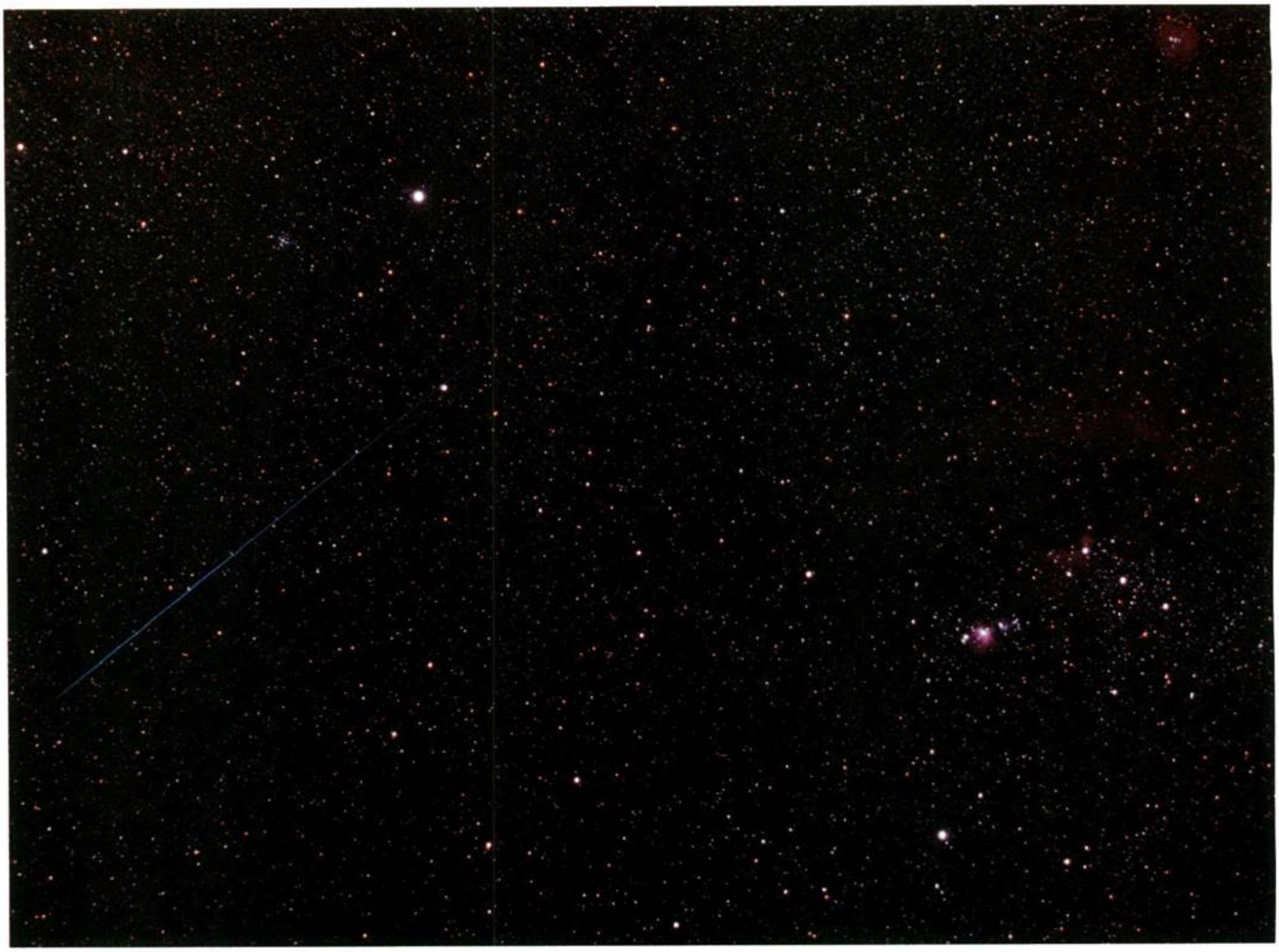


A Spectacular Halo Surrounds the Sun

Such displays are created by refraction of sunlight through ice crystals in the upper atmosphere

DOUGLAS C. ZUBENEL

(16mm lens at f/16, Kodak Royal Gold 25 film, 1⁄125-second exposure taken in July 1995)

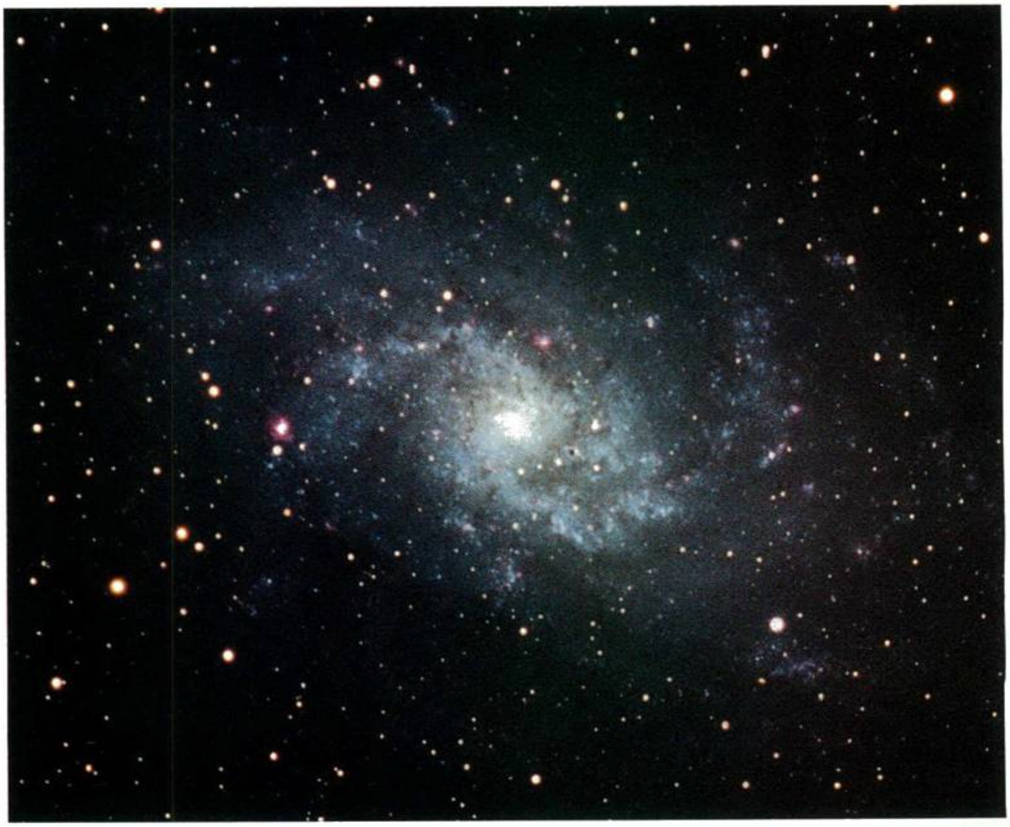


A Geminid Meteor Zips Past Canis Major

The wintertime meteor storm rivals the Perseid shower as the year's most active

FRANK ZULLO

(35mm lens at f/3.5, Fuji HG 400 film, 20-minute exposure taken in December 1993)

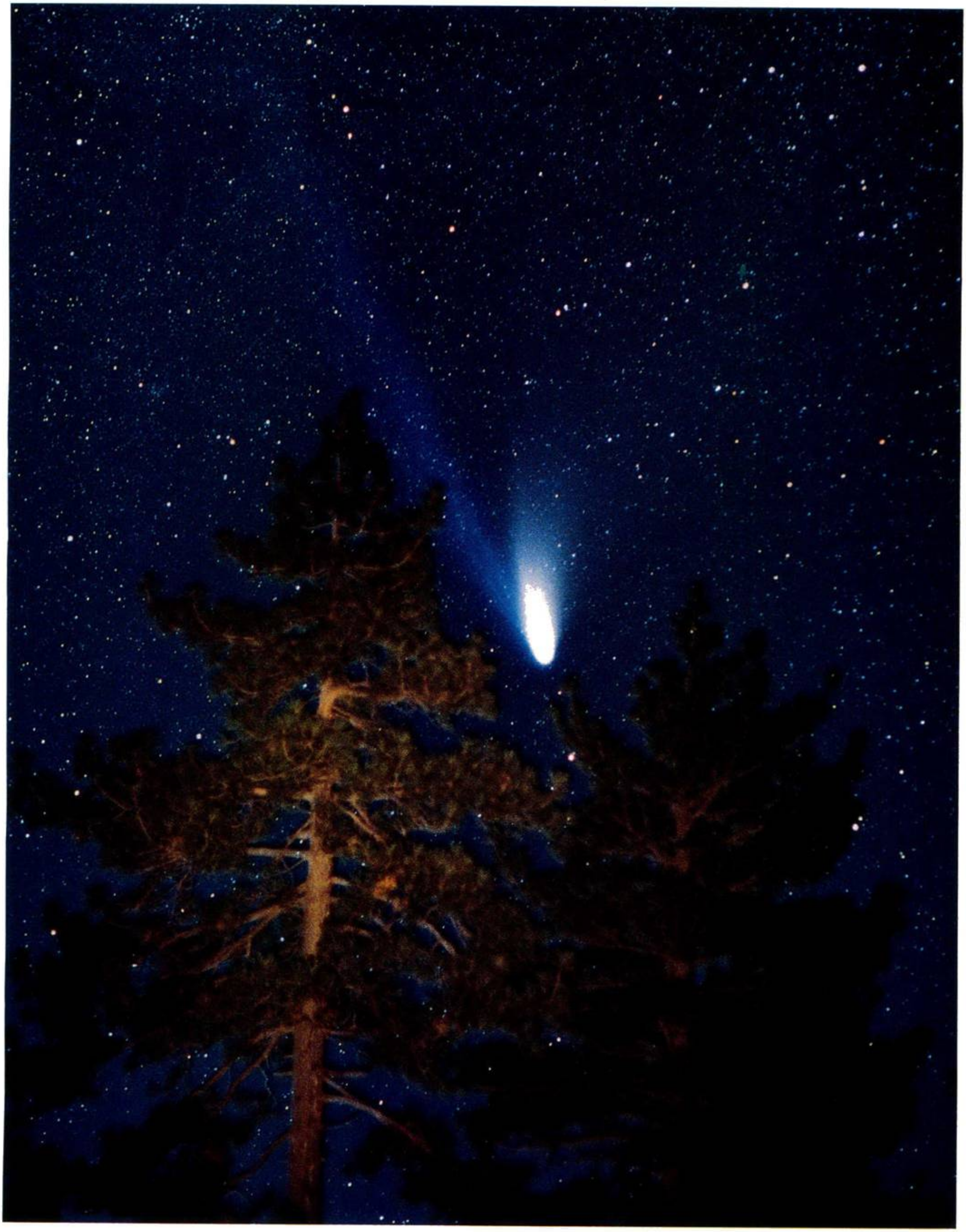


The Pinwheel Galaxy in Triangulum

The third ranking spiral in our Local Group shines brilliantly

CARL WEBER

(6-inch f/7 refractor, Pro 400 film, composite of 60-minute unhypered and 45-minute hypered exposures)

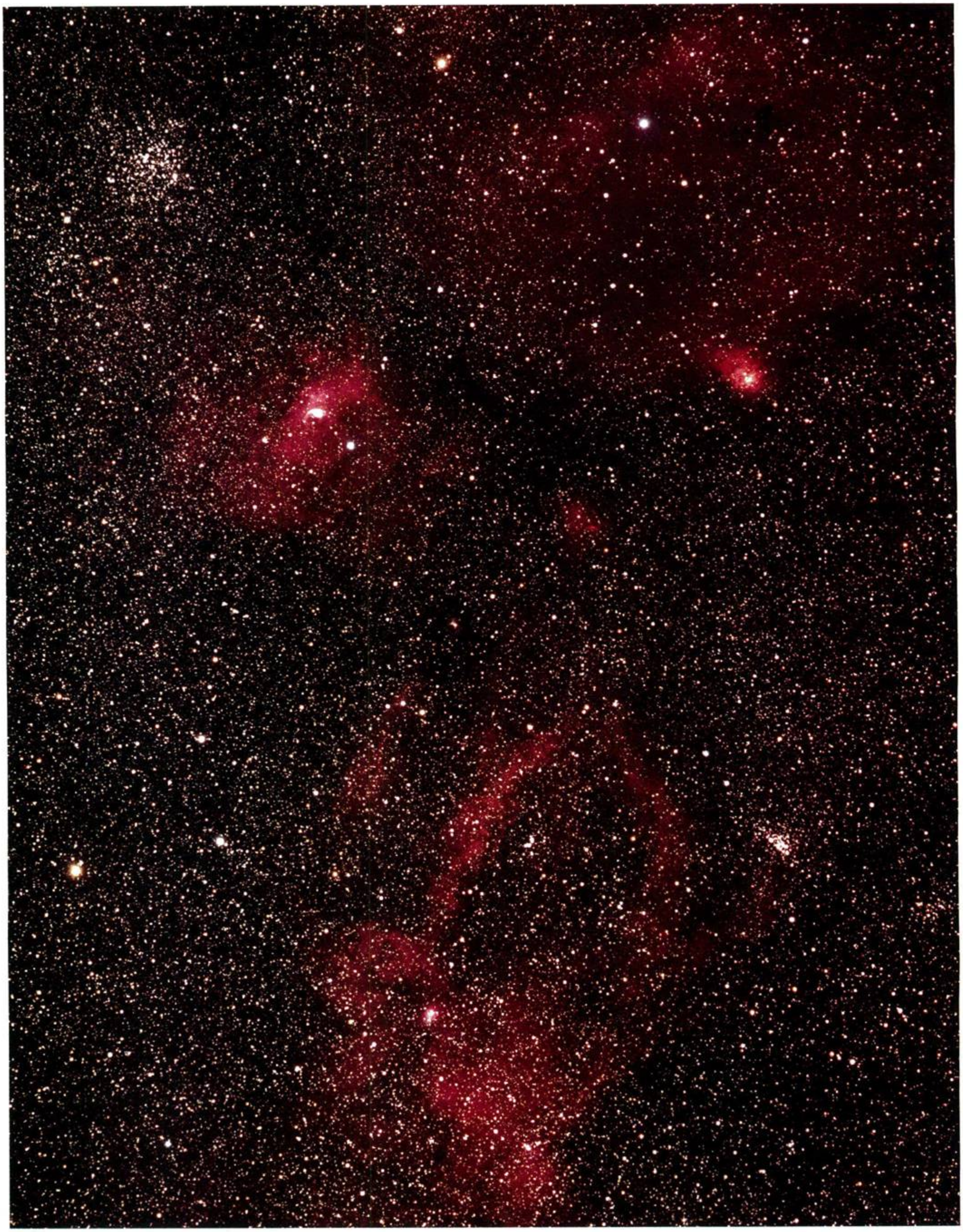


Comet Hale-Bopp over the California Pine Trees

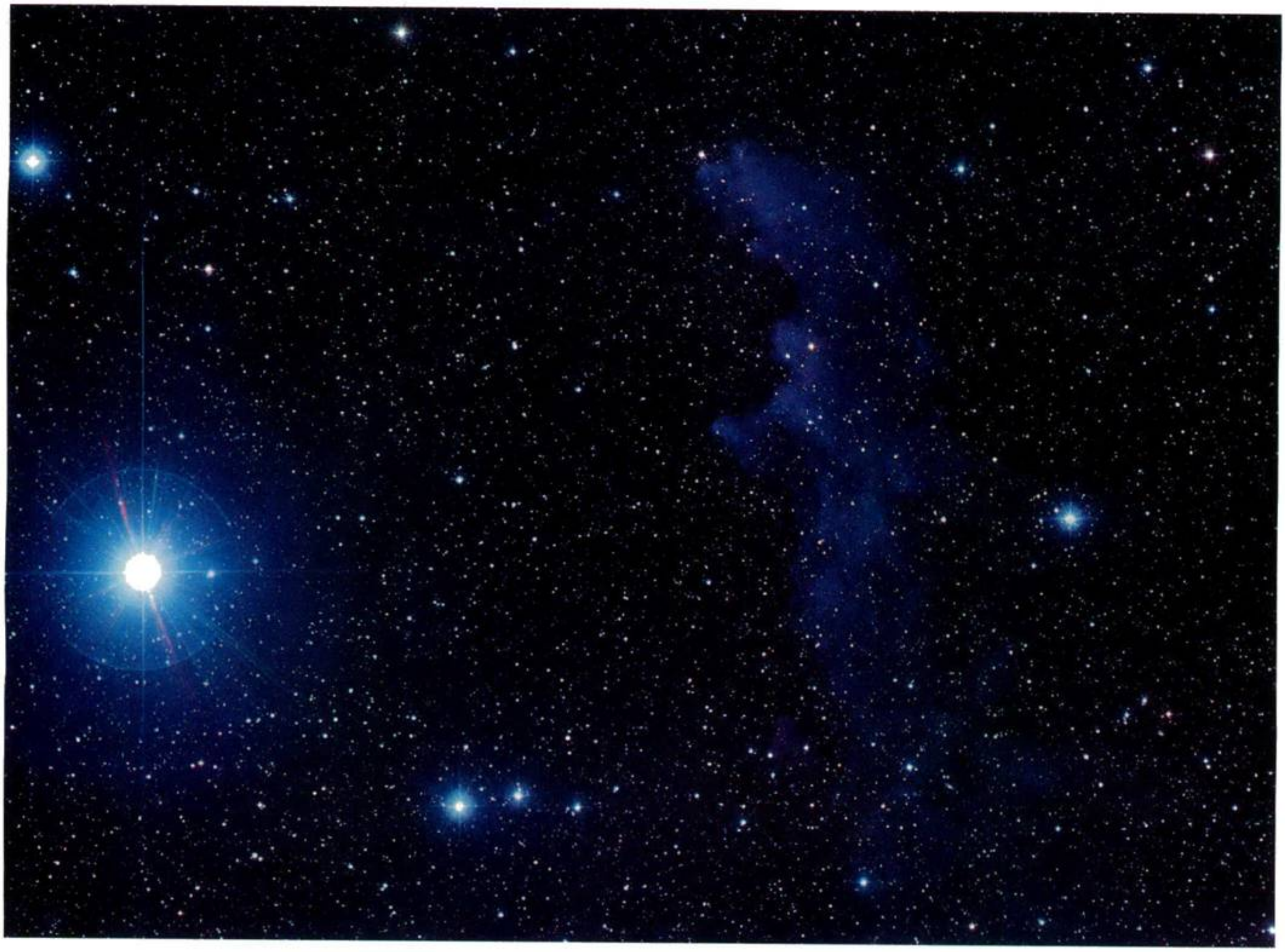
The photographer *illuminated* the pines with a flashlight

JERRY SCHAD

(85mm lens at f/1.7, P1600 film pushed to ISO 3200, 60-second exposure taken March 8, 1997)



Brilliant Nebulosity in Cassiopeia
The field includes the Bubble Nebula (left, above center) and star clusters M52 (top left) and NGC 7510
TONY AND DAPHNE HALLAS



The Witch Head Nebula (IC 2118) in Eridanus

The brilliant star at left is Orion's brightest sun, Rigel

BILL AND SALLY FLETCHER

(8-inch f/1.5 Schmidt camera, Tech Pan film, composite of 16-minute red, 58-minute green, and 68-minute blue exposures)

Last Quarter Moon over Borrego Springs, California

Orion dominates the star scene as it rises at upper right

JERRY SCHAD

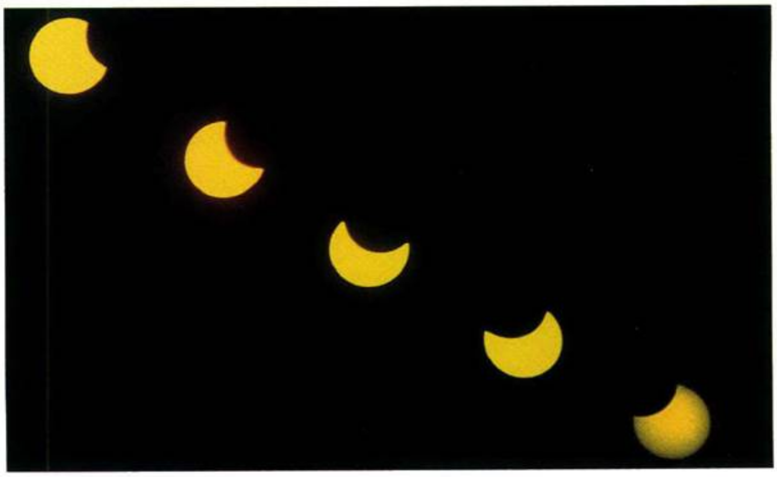
(24mm lens at f/1.4, Ektachrome P1600 film pushed to ISO 3200, 40-second exposure)

A Brilliant Aurora Masks Comet Hale-Bopp

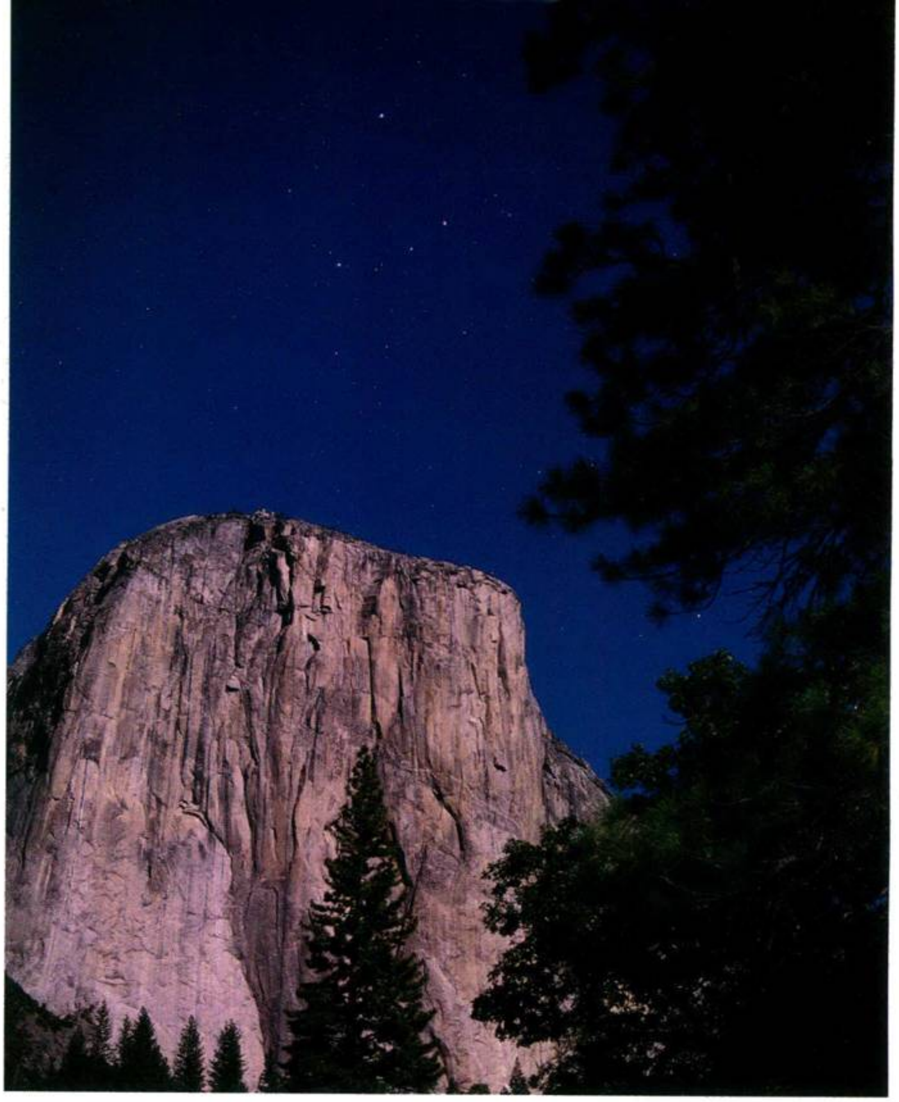
The comet was at its brightest when this image was created

BRYCE HEARTWELL

(35mm lens at f/3.5, Super G 800 film, 15-second exposure on April 10, 1997)



The Partial Solar Eclipse of October 12, 1996
Visible from Newfoundland to Moscow, the eclipse was here photographed from Italy
FABRIZIO MELANDRI
(200mm lens at f/4.5, Velvia 50 film, composite of 1/125-second exposures)



Cassiopeia Rises over El Capitan at Yosemite National Park

The moon illuminated the granite shaft; the photographer lit up the foreground trees with a flash

FRANK ZULLO

(35mm lens at f/2.5, Provia 100 film pushed to ISO 400, 23-second exposure)

The Elusive Supernova Remnant Simeis 147 in Taurus

This extremely faint object challenges photographers let alone observers

MICHAEL STECKER

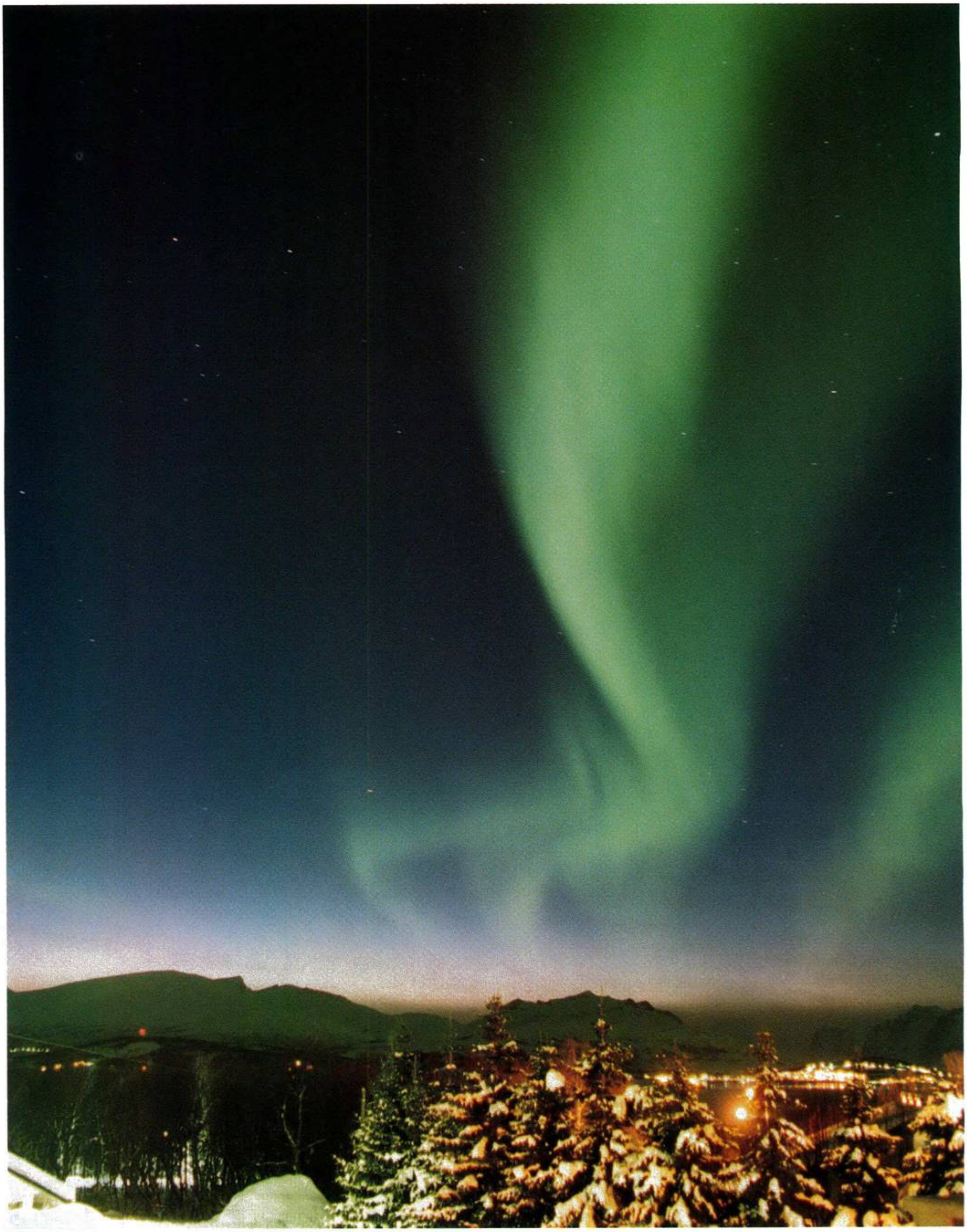
(5-inch f/4.5 refractor, hypered Tech Pan film, 120-minute exposure using a Wratten #25A filter)

The Moon near First Quarter

Note the bright ray system surrounding the crater Copernicus, left of center

CESAR DESCORDES

(9-inch f/13 reflector, Tech Pan film, taken September 11, 1994)

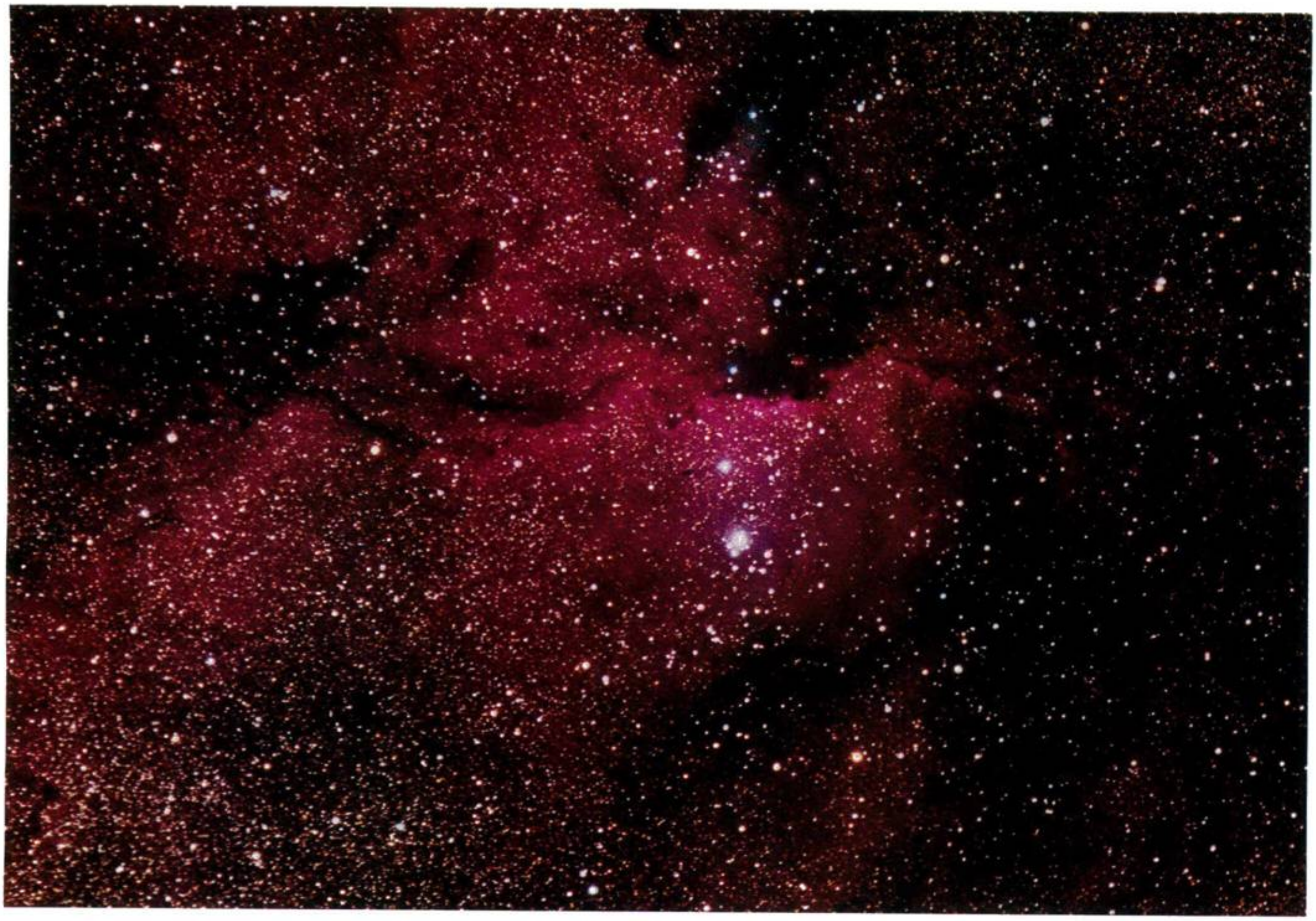


A Brilliant Aurora Paints Rays and Arcs over Norway

The shimmering display was photographed from near Tromsø

HUNRICH BASEMANN

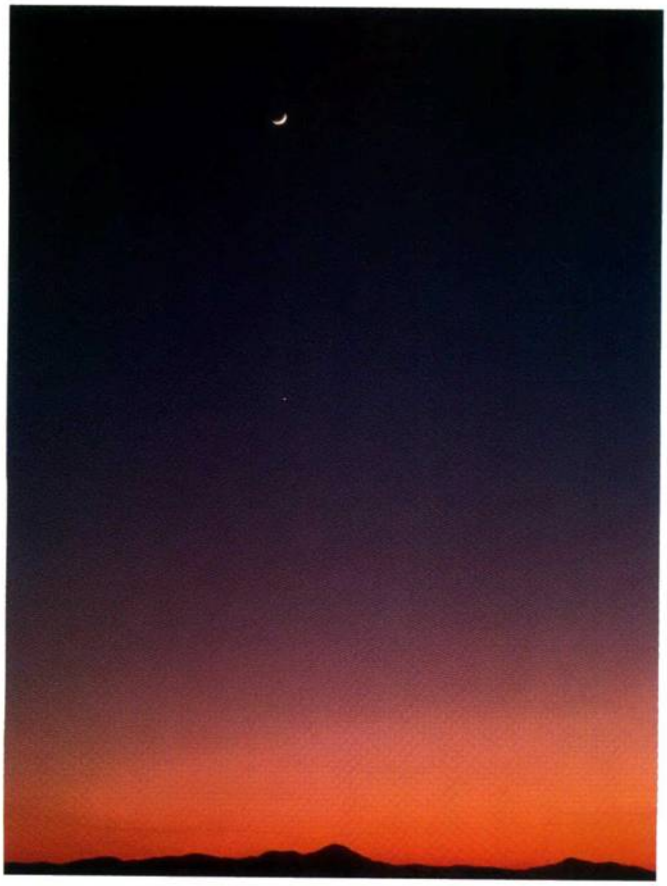
(50mm f/1.7 lens, Kodak Gold 400 film, 32-second exposure taken February 8, 1997)



Emission Nebula NGC 6188 in Ara
The elusive nebulosity was recorded from the Atacama Desert in Chile

MICHAEL STECKER

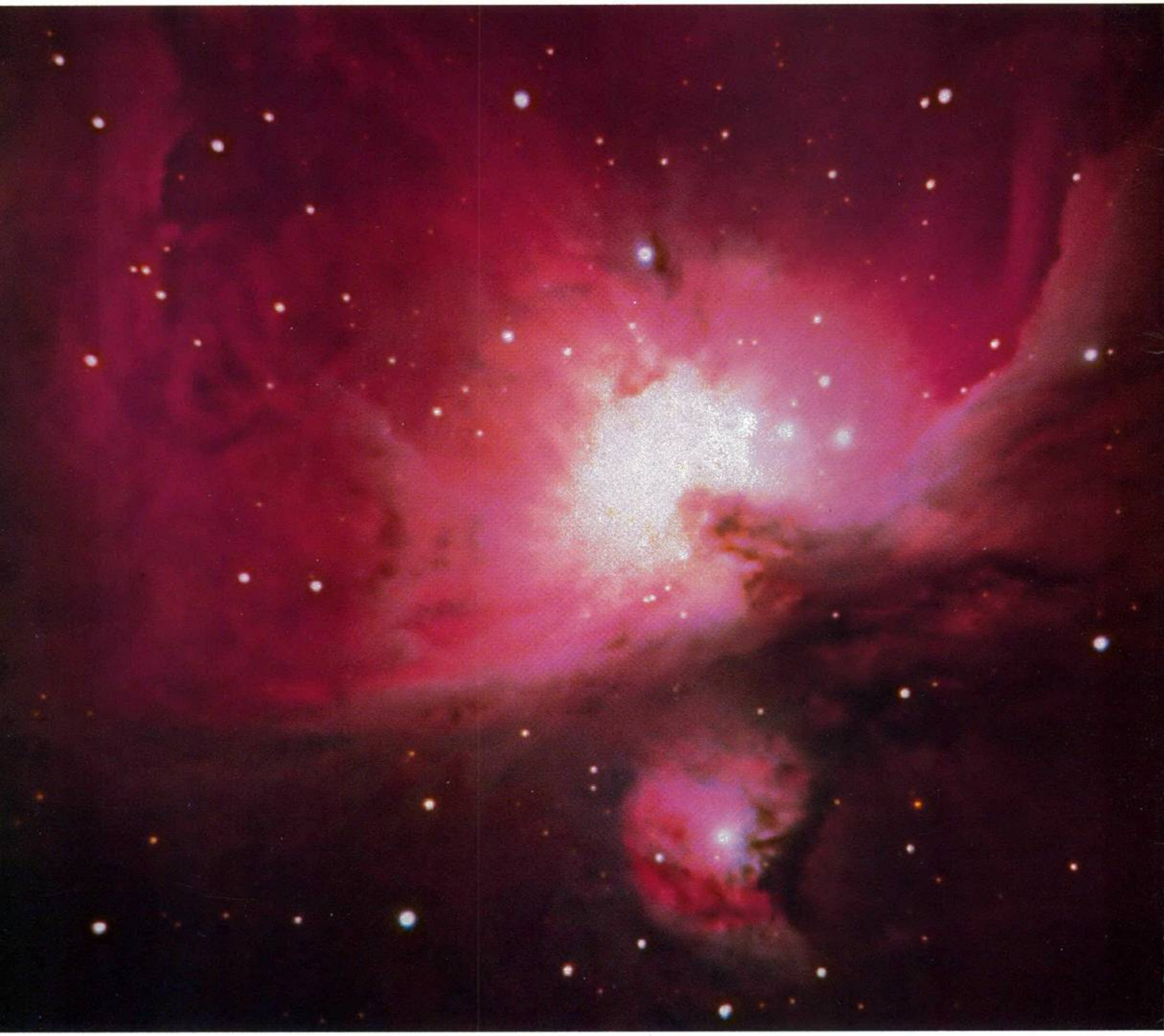
(5-inch f/6 refractor, hypered Fuji HG 400 film, composite of two 60-minute exposures)



Venus and a Young Moon in Evening Twilight
Arrayed in front of the stars of Capricornus, Venus shone at a dazzling magnitude −4.0

TIM BARNWELL

(Taken December 26, 1995 near Mt. Pisgah, North Carolina)



The Orion Nebula

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JAMES R. FOSTER

(11-inch SCT at f/11, hypered Kodak PPF film, composite of 40-minute, 12-minute, and 3-minute exposures)

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